Lower Colorado River Multi-Species Conservation Program

Balancing Resource Use and Conservation

Western Yellow-billed Cuckoo (*Coccyzus americanus occidentalis*) (YBCU) Basic Conceptual Ecological Model for the Lower Colorado River

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Bureau of Reclamation

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Lower Colorado River Multi-Species Conservation Program

Western Yellow-billed Cuckoo (*Coccyzus americanus occidentalis*) (YBCU) Basic Conceptual Ecological Model for the Lower Colorado River

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ACRONYMS AND ABBREVIATIONS

CEM	conceptual ecological model
ha	hectare(s)
LCR	lower Colorado River
LCR MSCP	Lower Colorado River Multi-Species Conservation Program
Reclamation	Bureau of Reclamation
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
YBCU	western yellow-billed cuckoo (*Coccyzus americanus occidentalis*)

Symbols

°C	degrees Celsius
>	greater than
≥	greater than or equal to
<	less than
%	percent
±	plus or minus

Definitions

For the purposes of this document, vegetation layers are defined as follows:

Canopy – The canopy is the uppermost strata within a plant community. The canopy is exposed to the sun and captures the majority of its radiant energy.

Understory – The understory comprises plant life growing beneath the canopy without penetrating it to any extent. The understory exists in the shade of the canopy and usually has lower light and higher humidity levels. The understory includes subcanopy trees and the shrub and herbaceous layers.

Shrub layer – The shrub layer is comprised of woody plants between 0.5 and 2.0 meters in height.

Herbaceous layer – The herbaceous layer is most commonly defined as the forest stratum composed of all vascular species that are 0.5 meter or less in height.

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Attachment

1 Species Conceptual Ecological Model Methodology for the Lower Colorado River Multi-Species Conservation Program

2 Western Yellow-billed Cuckoo Habitat Data

Foreword

The Lower Colorado River Multi-Species Conservation Program (LCR MSCP) Habitat Conservation Plan requires the creation, and long-term stewardship, of habitat for 20 covered species. This is both an exciting and daunting challenge – exciting, in that success would mean a major conservation achievement in the lower Colorado River landscape, and daunting, in that we need to simultaneously manage our lands for the benefit of 20 species in a mosaic of land cover types. To do so, we need to develop a common understanding of the habitat requirements of each species and the stewardship required to meet those needs.

To provide a framework to capture and share the information that forms the foundation of this understanding, conceptual ecological models (CEMs) for each covered species have been created under the LCR MSCP's Adaptive Management Program. The LCR MSCP's conceptual ecological models are descriptions of the functional relationships among essential components of a species' life history, including its habitat, threats, and drivers. They tell the story of "what's important to the animal" and how our stewardship and restoration actions can change those processes or attributes for the betterment of their habitat. As such, CEMs can provide:

- A synthesis of the current understanding of how a species' habitat works. This synthesis can be based on the published literature, technical reports, or professional experience.
- Help in understanding and diagnosing underlying issues and identifying land management opportunities.
- A basis for isolating cause and effect and simplifying complex systems. These models also document the interaction among system drivers.
- A common (shared) framework or "mental picture" from which to develop management alternatives.
- A tool for making qualitative predictions of ecosystem responses to stewardship actions.
- A way to flag potential thresholds from which system responses may accelerate or follow potentially unexpected or divergent paths.
- A means by which to outline further restoration, research, and development and to assess different restoration scenarios.

- A means of identifying appropriate monitoring indicators and metrics.

- A basis for implementing adaptive management strategies.

Most natural resource managers rely heavily upon CEMs to guide their work, but few explicitly formulate and express the models so they can be shared, assessed, and improved. When this is done, these models provide broad utility for ecosystem restoration and adaptive management.

Model building consists of determining system parts, identifying the relationships that link these parts, specifying the mechanisms by which the parts interact, identifying missing information, and exploring the model's behavior (Heemskerk et al. 2003[1]). The model building process can be as informative as the model itself, as it reveals what is known and what is unknown about the connections and causalities in the systems under management.

It is important to note that CEMs are not meant to be used as prescriptive management tools but rather to give managers the information needed to help inform decisions. These models are conceptual and qualitative. They are not intended to provide precise, quantitative predictions. Rather, they allow us to virtually "tweak the system" free of the constraints of time and cost to develop a prediction of how a system might respond over time to a variety of management options; for a single species, a documented model is a valuable tool, but for 20 species, they are imperative. The successful management of multiple species in a world of competing interests (species versus species), potentially conflicting needs, goals, and objectives, long response times, and limited resources, these models can help land managers experiment from the safety of the desktop. Because quantitative data can be informative, habitat parameters that have been quantified in the literature are presented (in attachment 2) in this document for reference purposes.

These models are intended to be "living" documents that should be updated and improved over time. The model presented here should not be viewed as a definitive monograph of a species' life history but rather as a framework for capturing the knowledge and experience of the LCR MSCP's scientists and land stewards. While ideally the most helpful land management tool would be a definitive list of do's and don'ts, with exact specifications regarding habitat requirements that would allow us to engineer exactly what the species we care about need to survive and thrive, this is clearly not possible. The fact is, that despite years of active management, observation, and academic research on many of the LCR MSCP species of concern, there may not be enough data to support developing such detailed, prescriptive land management.

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[1] Heemskerk, M., K. Wilson, and M. Pavao-Zuckerman. 2003. Conceptual models as tools for communication across disciplines. Conservation Ecology 7(3):8. http://www.consecol.org/vol7/iss3/art8/

The CEMs for species covered under the LCR MSCP are based on, and expand upon, methods developed by the Sacramento-San Joaquin Delta Ecosystem Restoration Program (ERP): https://www.dfg.ca.gov/ERP/conceptual_models.asp. The ERP is jointly implemented by the California Department of Fish and Wildlife, U.S. Fish and Wildlife Service, and National Marine Fisheries Service. The Bureau of Reclamation (Reclamation) participates in this program. (See attachment 1 for an introduction to the CEM process.)

Many of the LCR MSCP covered species are migratory. These models only address the species' life history as it relates to the lower Colorado River and specifically those areas that are potentially influenced by LCR MSCP land management. The models DO NOT take into account ecological factors that influence the species at their other migratory locations.

Finally, in determining the spatial extent of the literature used in these models, the goals and objectives of the LCR MSCP were taken into consideration. For species whose range is limited to the Southwest, the models are based on literature from throughout the species' range. In contrast, for those species whose breeding range is continental (e.g., yellow-billed cuckoo) or west-wide, the models primarily utilize studies from the Southwest.

How to Use the Models

There are three important elements to each CEM:

(1) The narrative description of the species' various life stages, critical biological activities and processes, and associated habitat elements.

(2) The figures that provide a visual snapshot of all the critical factors and causal links for a given life stage.

(3) The associated workbooks. Each CEM has a workbook that includes a worksheet for each life stage.

This narrative document is a basic guide, meant to summarize information on the species' most basic habitat needs, the figures are a graphic representation of how these needs are connected, and the accompanying workbook is a tool for land managers to see how on-the-ground changes might potentially change outcomes for the species in question. Reading, evaluating, and using these CEMs requires that the reader understand all three elements; no single element provides all the pertinent information in the model. While it seems convenient to simply read the narrative, we strongly recommend the reader have the figures and workbook open and refer to them while reviewing this document.

It is also tempting to see these products, once delivered, as “final.” However, it is more accurate to view them as “living” documents, serving as the foundation for future work. Reclamation will update these products as new information is available, helping to inform land managers as they address the on-the-ground challenges inherent in natural resource management.

The knowledge gaps identified by these models are meant to serve only as an example of the work that could be done to further complete our understanding of the life history of the LCR MSCP covered species. However, this list can in no way be considered an exhaustive list of research needs. Additionally, while identifying knowledge gaps was an objective of this effort, evaluating the feasibility of addressing those gaps was not. Finally, while these models were developed for the LCR MSCP, the identified research needs and knowledge gaps reflect a current lack of understanding within the wider scientific community. As such, they may not reflect the current or future goals of the LCR MSCP. They are for the purpose of informing LCR MSCP decisionmaking but are in no way meant as a call for Reclamation to undertake research to fill the identified knowledge gaps.

John Swett, Program Manager, LCR MSCP
Bureau of Reclamation
September 2015

Executive Summary

This document presents a conceptual ecological model (CEM) for the western yellow-billed cuckoo (*Coccyzus americanus occidentalis*) (YBCU). The purpose of this model is to help the Bureau of Reclamation (Reclamation), Lower Colorado River Multi-Species Conservation Program (LCR MSCP), identify areas of scientific uncertainty concerning YBCU ecology, the effects of specific stressors, the effects of specific management actions aimed at species habitat restoration, and the methods used to measure YBCU habitat and population conditions. (Note: Attachment 1 provides an introduction to the CEM process. We recommend that those unfamiliar with this process read the attachment before continuing with this document.)

The identified research questions and gaps in scientific knowledge that are the result of this modeling effort serve as examples of topics the larger scientific community could explore to improve the overall understanding of the ecology of this species. These questions may or may not be relevant to the goals of the LCR MSCP. As such, they are not to be considered guidance for Reclamation or the LCR MSCP, nor are these knowledge gaps expected to be addressed under the program.

CONCEPTUAL ECOLOGICAL MODELS

CEMs integrate and organize existing knowledge concerning: (1) what is known about an ecological resource, with what certainty, and the sources of this information, (2) critical areas of uncertain or conflicting science that demand resolution to better guide management planning and action, (3) crucial attributes to use while monitoring system conditions and predicting the effects of experiments, management actions, and other potential agents of change, and (4) how we expect the characteristics of the resource to change as a result of altering its shaping/controlling factors, including those resulting from management actions.

The CEM applied to YBCU expands on the methodology developed for the Sacramento-San Joaquin River Delta Regional Ecosystem Restoration Implementation Plan (DiGennaro et al. 2012). The model distinguishes the major life stages or events through which the individuals of a species must pass to complete a full life cycle. It then identifies the factors that shape the likelihood that individuals in each life stage will survive to the next stage in the study area and thereby shapes the abundance, distribution, and persistence of the species in that area.

Specifically, the YBCU conceptual ecological model has five core components:

- **Life stages** – These consist of the major growth stages and critical events through which an individual YBCU must pass in order to complete a full reproductive cycle.

- **Life-stage outcomes** – These consist of the biologically crucial outcomes of each life stage, including the number of individuals recruited to the next life stage or age class within a single life stage (recruitment rate), or the number of offspring produced (fertility rate).

- **Critical biological activities and processes** – These consist of activities in which the species engages and the biological processes that take place during each life stage that significantly beneficially or detrimentally shape the life-stage outcome rates for that life stage.

- **Habitat elements** – These consist of the specific habitat conditions, the abundance, spatial and temporal distributions, and other qualities of which significantly beneficially or detrimentally affect the rates of the critical biological activities and processes for each life stage.

- **Controlling factors** – These consist of environmental conditions and dynamics – including human actions – that determine the abundance, spatial and temporal distributions, and other qualities of the habitat elements for each life stage. Controlling factors are also called "drivers."

The CEM identifies the causal relationships among these components for each life stage. A causal relationship exists when a change in one condition or property of a system results in a change in some other condition or property. A change in the first condition is said to cause a change in the second condition. The CEM method applied here assesses four variables for each causal relationship: (1) the character and direction of the effect, (2) the magnitude of the effect, (3) the predictability (consistency) of the effect, and (4) the certainty of a present scientific understanding of the effect. CEM diagrams and a linked spreadsheet tool document all information on the model components and their causal relationships.

CONCEPTUAL ECOLOGICAL MODEL STRUCTURE

The YBCU conceptual ecological model addresses the western YBCU throughout its breeding range but does not address the biology of the YBCU during migration or in its winter range. The model does not specifically address the eastern population of YBCU. The model thus addresses the landscape as a whole rather than any single reach or managed area within the lower Colorado River (LCR).

The primary sources of information used for the YBCU conceptual ecological model are Laymon et al. (1997), Hughes (1999), Halterman (2002), McNeil et al. (2013b), Reclamation (2004, 2008), and BIO-WEST, Inc. (2005). These publications summarize and cite large bodies of earlier studies; where appropriate, those earlier studies are cited directly. The model also integrates numerous additional sources, particularly reports and articles completed since these publications; information on current research projects; publications resulting from research outside of the LCR; and the expert knowledge of LCR MSCP biologists. Our purpose is not to provide an updated literature review but to integrate the available information and knowledge into a CEM so it can be used for adaptive management.

The YBCU conceptual ecological model distinguishes and assesses three life stages and their associated outcomes as follows (table ES-1):

Table ES-1.—Outcomes of each of the three life stages of YBCU

Life stage	Life-stage outcome(s)
1. Nest	• Survival
2. Juvenile	• Survival
3. Breeding adult	• Survival • Reproduction

The model distinguishes 8 critical biological activities and processes relevant to 1 or more of these 3 life stages and their outcomes, 19 habitat elements relevant to 1 or more of these 8 critical biological activities and processes for 1 or more life stages, and 9 controlling factors that affect 1 or more of these 19 habitat elements. Because the LCR is a highly regulated system, the controlling factors almost exclusively concern human activities.

The eight critical biological activities and processes identified across all life stages are: disease, eating, foraging, molt, nest attendance, nest site selection, predation, and temperature regulation. The 19 habitat elements identified across all life stages are: anthropogenic disturbance, brood size, canopy closure, community type, diversity of vegetation, food availability, genetic diversity and infectious agents, humidity, intermediate structure, linear width of patch, local hydrology, matrix community, parental feeding behavior, parental nest attendance, patch phenology, patch size, predator density, temperature, and tree density. The nine controlling factors identified across all habitat elements are:

fire management, grazing, mechanical thinning, natural thinning, nuisance species introduction and management, pesticide/herbicide application, planting regime, recreational activities, and water storage-delivery system design and operation.

RESULTS

The analysis of the causal relationships shows which critical biological activities and processes most strongly support or limit each life-stage outcome in the present system, which habitat elements most strongly affect the rates of these critical biological activities and processes, and which controlling factors most strongly affect the abundance, distribution, or condition of these habitat elements.

The analysis identifies several critical biological activities and processes that significantly affect survivorship across multiple life stages. Highlights of the results include the following:

- Eating, foraging, and predation are the most important critical biological activities and processes affecting survival of YBCU in all life stages (Fontaine and Martin 2006; Martin 2011). Hughes (1999) suggests that YBCU populations are often limited by food availability, implying that the YBCU's ability to forage is especially important. Other processes, such as disease, molt, and temperature regulation can be very important, but are less understood, especially within the LCR.

- Only two processes directly affect reproduction—nest attendance and nest site selection. Nest site selection is especially important, as it can indirectly influence survival of YBCU in all life stages. For example, good nest sites may be in close proximity to more food, have fewer predators, and have fewer diseases present.

- Nest site selection is by far affected by the most habitat variables likely because this critical biological activity and process is not only the most researched but also because during the breeding season, nest site selection determines if the birds are present or not.

- Predation is also affected by a large number of habitat elements, including anthropogenic disturbance, canopy closure, community type, intermediate structure, linear width of patch, patch size, predator density, and tree density, along with parental feeding behavior and parental nest attendance. Patch size affects predation rates because of its effects on the proportion of edge (Theimer et al. 2011; Laymon and Halterman 1989 and references therein). Predator density affects predation rates (Schmidt et al. 2001). Predation is affected by edges (reviewed by Yahner 1988), and linear width affects how much of the area of a patch is affected by edge effects.

- Nest attendance is strongly affected by four habitat elements, including anthropogenic disturbance, brood size, predator density, and temperature. Anthropogenic disturbance may cause adult birds to flush and stay away from the nest (Burhans and Thompson, III 2001; U.S. Fish and Wildlife Service 2002a). Brood size affects the amount of time YBCU must spend foraging versus attending the nest (Hughes 1999). Predator density certainly affects predation rates (Schmidt et al. 2001). The temperature affects nest attendance of birds along the LCR (Theimer et al. 2011).

Finally, the analysis highlights several potentially important causal relationships about which scientific understanding remains low. These may warrant attention to determine if improved understanding might provide additional management options for improving YBCU survivorship and recruitment along the LCR. Specifically, the findings suggest a need to improve the understanding of the following:

- The effects of predation on juveniles and adults is poorly understood, whereas nest predation is better studied. This likely reflects the relative ease of studying depredation of nests versus free-flying birds. Since the persistence or population growth of YBCU populations is as sensitive to the survival of adults and juveniles as nest survival, more information regarding depredation on YBCU in these life stages would be valuable.

- We have classified the relationship between nest site selection and patch size as poorly understood. Past authors agree patch size is important (e.g., Laymon and Halterman 1989; Halterman 1991; Hughes 1999), but the home ranges and the sizes of the patches used varies regionally. For example, McNeil et al. (2013a) found that YBCU had smaller home ranges (approximately 21 hectares) in restoration sites than were observed on more natural sites (approximately 38 and 56 hectares) at other locations.

- Several authors mention food, especially cicadas (Cicadidae) and other large insects, as important for YBCU (Laymon et al. 1997; Hughes 1999; Wiggins 2005; Smith et al. 2006). We have therefore classified the relationship between food availability and foraging as well understood. However, although the relationship between food availability and YBCU persistence likely holds across its range, the specific prey base at LCR MSCP restoration sites is poorly known (McNeil et al. 2013).

- YBCU are sensitive to disturbance of all kinds, and a better understanding of the impacts of all forms of anthropogenic disturbance would be valuable.

The research questions and gaps in scientific knowledge identified in this modeling effort serve as examples of topics the larger scientific community could explore to improve the overall understanding of the ecology of YBCU. These questions may or may not be relevant to the goals of the LCR MSCP. As such, they are not to be considered guidance for Reclamation or the LCR MSCP, nor are these knowledge gaps expected to be addressed under the program.

Chapter 1 – Introduction

This document presents a conceptual ecological model (CEM) for the western yellow-billed cuckoo (*Coccyzus americanus occidentalis*) (YBCU). The purpose of this model is to help the Bureau of Reclamation (Reclamation), Lower Colorado River Multi-Species Conservation Program (LCR MSCP), identify areas of scientific uncertainty concerning YBCU ecology, the effects of specific stressors, the effects of specific management actions aimed at species habitat restoration, and the methods used to measure YBCU habitat and population conditions. The CEM methodology follows that developed for the Sacramento-San Joaquin River Delta Regional Ecosystem Restoration Implementation Plan (DiGennaro et al. 2012), with modifications. (Note: Attachment 1 provides an introduction to the CEM process. We recommend that those unfamiliar with this process read the attachment before continuing with this document.)

The CEM specifically addresses the YBCU population along the rivers and lakes of the lower Colorado River (LCR) and other protected areas. The model thus addresses the landscape as a whole rather than any single reach or managed area.

The most widely used sources of information for the YBCU conceptual ecological model are Laymon et al. (1997), Hughes (1999), Halterman (2002), McNeil et al. (2013b), Reclamation (2004, 2008), and BIO-WEST, Inc. (2005). These publications summarize and cite large bodies of earlier studies. Where appropriate, those earlier studies are cited directly. The CEM also integrates numerous additional sources, including reports and articles completed since the aforementioned publications; information on current research projects; publications resulting from research outside of the LCR; and the expert knowledge of LCR MSCP avian biologists. The purpose of the conceptual ecological model is not to provide an updated literature review but to integrate the available information and knowledge into a CEM so it can be used for adaptive management.

This document is organized as follows: The remainder of chapter 1 provides a general description of the reproductive ecology of the western yellow-billed cuckoo, the purpose of the model, and introduces the underlying concepts and structure of the CEM. Succeeding chapters present and explain the model for YBCU along the LCR and evaluate the implications of this information for management, monitoring, and research needs.

WESTERN YELLOW-BILLED CUCKOO REPRODUCTIVE ECOLOGY

Adult YBCU arrive on their LCR breeding grounds during mid- to late May (Halterman 2002; Reclamation 2008), with pair formation occurring from late

June to mid-July (Halterman 1991). Nesting activity usually peaks during July and early August (Halterman 2002; Reclamation 2008; McNeil et al. 2013). Both parents participate in nest site selection and nest construction and share in incubation and feeding of young (Halterman 1991; Hughes 1999). Incubation begins with the first egg laid and usually lasts 9 to 11 days, with eggs hatching asynchronously (Halterman 2002; Reclamation 2008). The entire nestling period, from the time eggs are laid until fledging, lasts roughly 17 days (Laymon and Halterman 1985; McNeil et al. 2013). Most chicks fledge on day 6, although nestlings can be present 5 to 9 days after hatching (Halterman 2002; Reclamation 2008 and references therein). After fledging, juveniles are dependent on adults for food for 2 weeks (Laymon and Halterman 1985), although adults may feed the young for a total of 3 to 4 weeks (Halterman 1991; McNeil et al. 2013).

The frequency of brood parasitism is poorly understood (Hughes 1999; Wiggins 2005), although YBCU are known to be intra- and interspecific brood parasites. YBCU are mostly monogamous; however, approximately 30 percent of nests may have helpers, which are typically young, unrelated males that feed nestlings (Laymon 1998; Hughes 1999). YBCU populations along the LCR likely contain an abundance of "floaters," adult birds that do not breed (McNeil et al. 2013).

Cuckoos primarily feed on larger bodied insects such as caterpillars (Lepidoptera), cicadas (Cicadidae), and katydids (Tettigoniidae)(Laymon 1980 *in* Hughes 1999), and in some areas of their range, their nesting activity coincides with cicada emergences (Hughes 1999), making both the density and phenology of cicada emergence important for YBCU in the Southwestern United States. The abundance and condition of the food supply affects adult health and the growth and development of the young during the nest and juvenile stages.

CONCEPTUAL ECOLOGICAL MODEL PURPOSES

Adaptive management of natural resources requires a framework to help managers understand the state of knowledge about how a resource "works," what elements of the resource they can affect through management, and how the resource will likely respond to management actions. The "resource" may be a population, species, habitat, or ecological complex. The best such frameworks incorporate the combined knowledge of many professionals accumulated over years of investigations and management actions. CEMs capture and synthesize this knowledge (Fischenich 2008; DiGennaro et al. 2012).

CEMs explicitly identify: (1) the variables or attributes that best characterize resource conditions, (2) the factors that most strongly shape or control these variables under both natural and altered (including managed) conditions, (3) the character, strength, and predictability of the ways in which these factors do this shaping/controlling, and (4) how the characteristics of the resource vary as a result of the interplay of its shaping/controlling factors.

By integrating and explicitly organizing existing knowledge in this way, a CEM summarizes and documents: (1) what is known, with what certainty, and the sources of this information, (2) critical areas of uncertain or conflicting science that demand resolution to better guide management planning and action, (3) crucial attributes to use while monitoring system conditions and predicting the effects of experiments, management actions, and other potential agents of change, and (4) how the characteristics of the resource would likely change as a result of altering its shaping/controlling factors, including those resulting from management actions.

A CEM thus translates existing knowledge into a set of explicit hypotheses. The scientific community may consider some of these hypotheses well tested, but others less so. Through the model, scientists and managers can identify which hypotheses, and the assumptions they express, most strongly influence management actions. The CEM thus helps guide management actions based on the results of monitoring and experimentation. These results indicate whether expectations about the results of management actions – as clearly stated in the CEM – have been met or not. Both expected and unexpected results allow managers to update the model, improving certainty about some aspects of the model while requiring changes to other aspects, to guide the next cycle of management actions and research. The CEM, through its successive iterations, becomes the record of improving knowledge and the ability to manage the system.

CONCEPTUAL ECOLOGICAL MODEL STRUCTURE FOR THE YBCU

The CEM methodology used here expands on that developed for the Sacramento-San Joaquin River Delta Regional Ecosystem Restoration Implementation Plan (DiGennaro et al. 2012). The expansion incorporates recommendations of Wildhaber et al. (2007), Kondolf et al. (2008), Burke et al. (2009), and Wildhaber (2011) to provide greater detail on causal linkages and outcomes and explicit demographic notation in the characterization of life-stage outcomes (McDonald and Caswell 1993). Attachment 1 provides a detailed description of the methodology. The resulting model is a “life history” model, as is common for CEMs focused on individual species (Wildhaber et al. 2007; Wildhaber 2011). That is, it distinguishes the major life stages or events through which the individuals of a species must pass to complete a full life cycle, including reproducing, and the biologically crucial outcomes of each life stage. These biologically crucial outcomes typically include the number of individuals recruited to the next life stage (e.g., juvenile to adult) or age class within a single life stage (recruitment rate), or the number of viable offspring produced (fertility rate). It then identifies the factors that shape the rates of these outcomes in the study area and thereby shapes the abundance, distribution, and persistence of the species in that area.

The YBCU conceptual ecological model has five core components as explained further in attachment 1:

- **Life stages** – These consist of the major growth stages and critical events through which the individuals of a species must pass in order to complete a full life cycle.

- **Life-stage outcomes** – These consist of the biologically crucial outcomes of each life stage, including the number of individuals recruited to the next life stage (e.g., juvenile to adult), or the number of offspring produced (fertility rate). The rates of the outcomes for an individual life stage depend on the rates of the critical biological activities and processes for that life stage.

- **Critical biological activities and processes** – These consist of the activities in which the species engages and the biological processes that take place during each life stage that significantly affect its life-stage outcomes rates. Examples of biological activities and processes for a bird species may include foraging, molt, nest site selection, and temperature regulation. Critical biological activities and processes typically are "rate" variables; the rate (intensity) of the activities and processes, taken together, determine the rate of recruitment of individuals to the next life stage.

- **Habitat elements** – These consist of the specific habitat conditions, the quality, abundance, and spatial and temporal distributions of which significantly affect the rates of the critical biological activities and processes for each life stage. The effects on critical biological activities and processes may be either beneficial or detrimental. Taken together, the suite of natural habitat elements for a life stage is called the "habitat template" for that life stage. Defining the natural habitat template may involve estimating specific thresholds or ranges of suitable values for particular habitat elements outside of which one or more critical biological activities or processes no longer fully support desired life-stage outcome rates – if the state of the science supports such estimates.

- **Controlling factors** – These consist of environmental conditions and dynamics – including human actions – that determine the quality, abundance, and spatial and temporal distributions of important habitat elements. Controlling factors are also called "drivers." There may be a hierarchy of such factors affecting the system at different scales of time and space (Burke et al. 2009). For example, the availability of suitable nest sites for a riparian nesting bird may depend on factors such as canopy closure, community type, humidity, and intermediate structure, which in turn may depend on factors such as water storage-delivery system design and operation (dam design, dam operations, and reservoir morphology), which in turn is shaped by climate, land use, vegetation, water demand, and watershed geology.

The CEM identifies these five components and the causal relationships among them that affect life-stage outcome rates. Further, the CEM assesses each causal information: (1) the character and direction of the effect, (2) the magnitude of the effect, (3) the predictability (consistency) of the effect, and (4) the status (certainty) of a present scientific understanding of the effect.

The CEM for each life stage thus identifies the causal relationships that most strongly support or limit the rates of its life-stage outcomes, support or limit the rate of each critical biological activity or process, and support or limit the quality, abundance, and distribution of each habitat element (as these affect other habitat elements or affect critical biological activities and processes). In addition, the model for each life stage highlights areas of scientific uncertainty concerning these causal relationships, the effects of specific management actions aimed at these relationships, and the suitability of the methods used to measure habitat and population conditions. Attachment 1 provides further details on the assessment of causal relationships, including the use of diagrams and a spreadsheet tool to record the details of the CEM and summarize the findings.

Chapter 2 – YBCU Life Stage Model

A life stage consists of a biologically distinct portion of the life cycle of a species during which individuals undergo distinct developments in body form and function, engage in distinct behaviors, use distinct sets of habitats, and/or interact with their larger ecosystems in ways that differ from those associated with other life stages. This chapter proposes a life stage model for YBCU along the LCR on which to build the CEM.

INTRODUCTION TO THE YBCU LIFE CYCLE

In many studies of avian demography, nest survival is considered integral in the reproduction of adults because adults are heavily invested in the care of eggs and nestlings (Etterson et al. 2011). However, we treat the nest stage as separate from adult reproduction because nest success of YBCU has been the subject of intense study, and the wealth of information learned from studies of YBCU nest success is best presented separately.

We also note that in a past version of this model we treated the egg and nestling stages as separate because they undergo different processes—e.g., eggs do not need to eat or molt. Additionally, parental investment changes over time, as cuckoos are less likely to abandon a nest as the nesting cycle advances (B. Raulston 2014, personal communication). However, we have here combined the egg and nestling phases of development into a nest stage because the eggs and nestlings occupy the same nest; therefore, management focused on the nest will cover both eggs and nestlings. Further, most research conducted on YBCU breeding has focused on the number of young fledged and not on the number of eggs hatched—meaning that most of the available information is on the habitat characteristics and management actions associated with success of the nest through both the incubation and brooding periods.

The migratory nature of the YBCU complicates its management. The LCR MSCP is mainly responsible for management on the breeding grounds, and we therefore focus on three life stages occurring within LCR MSCP lands—nest, juvenile, and breeding adult. YBCU management during migration and winter are certainly important but are outside of the scope of the LCR MSCP's responsibilities.

YBCU LIFE STAGE 1 – NEST

We consider the nest stage to be the first in the life cycle of the YBCU. It begins when the egg is laid and ends when the young fledge or the nest fails. Incubation begins with the first egg laid and usually lasts 9 to 11 days, with eggs hatching asynchronously (Halterman 2002; Reclamation 2008).

Nestlings are usually present 5 to 9 days after hatching, with most chicks fledging 6 days after hatching (Halterman 2002; Reclamation 2008 and references therein). The entire nestling period, from the time eggs are laid until fledging, lasts roughly 17 days (Laymon and Halterman 1985; McNeil et al. 2013), among the shortest nestling periods of any bird. Nestlings gain weight rapidly, adding 4.9 grams per day (Hughes 1999). The life-stage outcome from the nest stage is the survival of eggs and associated nestlings until fledging. It is important to note that the outcome of the nest stage is inherently tied to the behavior and condition of the parents.

YBCU LIFE STAGE 2 – JUVENILE

The juvenile stage begins at fledging and ends when the bird returns to the breeding grounds the next year. After fledging, juveniles are dependent on adults for food for 2 weeks (Laymon and Halterman 1985), although adults may feed the young for 3 to 4 weeks after fledging (Halterman 1991; McNeil et al. 2013). The life-stage outcome from the juvenile stage is the survival of the bird from fledging until the return to the breeding grounds the next calendar year.

YBCU LIFE STAGE 3 – BREEDING ADULT

The breeding adult stage begins when the bird returns to the breeding grounds after its first winter and ends when it departs the breeding grounds during fall migration. Generally, adults arrive on breeding grounds during mid- to late May (Halterman 2002; Reclamation 2008). Nesting can begin as early as late May (Halterman 2002) and continue into September, but it generally peaks during July and early August (Halterman 2002; Reclamation 2008; McNeil et al. 2013).

Pair formation occurs from late June to mid-July (Halterman 1991). Both parents participate in the placement and building of the nest as well as incubation and feeding of young (Halterman 1991; Hughes 1999). YBCU may double or even triple brood if sufficient resources exist (Reclamation 2008; McNeil et al. 2013).

Although YBCU are known to be intra- and interspecific brood parasites, the frequency of brood parasitism is poorly understood (Hughes 1999; Wiggins

2005), and it likely occurs more often than assumed (McNeil et al. 2013). YBCU are mostly monogamous; however, approximately 30 percent of nests may have helpers, which are typically young, unrelated males that feed nestlings (Laymon 1998; Hughes 1999). YBCU populations along the LCR likely contain an abundance of "floaters," adult birds that do not breed (McNeil et al. 2013). We have included breeding males and females as well as floaters and helpers in the breeding adult life stage because they have similar habitat requirements—especially for foraging—and therefore management directed at breeding adults will likely benefit all demographics present on the breeding grounds.

The life-stage outcomes for breeding adults are survival and reproduction—here defined as the production of eggs. Most studies of bird demography define fecundity—or the reproductive rates of adults—as the number of offspring fledged (Etterson et al. 2011). We have separated the nest stage from adult fecundity to more clearly display the information regarding nest success so that it can be better assessed by management. Therefore, adult reproduction involves the acts of pairing, site selection, nest building, and the production of eggs.

It is important to note that the post-breeding period—after breeding but before migration—is a significant part of a bird's life cycle. During the post-breeding period, adults of some species may prospect for potential future breeding areas or move into habitat types that differ from breeding areas but provide good conditions for migratory staging (Vega Rivera et al. 2003). However, 83 percent of YBCU captured along the LCR remain on their territories until they leave the area (McNeil et al. 2013), suggesting that habitat use by YBCU is constant while they are present along the LCR.

LIFE STAGE MODEL SUMMARY

Based on the information presented above, the YBCU conceptual ecological model distinguishes three life stages and their associated life-stage outcomes as shown in table 1 and figure 1. The life stages are numbered sequentially beginning with the nest.

Table 1.—Outcomes of each of the three life stages of YBCU

Life stage	Life-stage outcome(s)
1. Nest	• Survival
2. Juvenile	• Survival
3. Breeding adult	• Survival • Reproduction

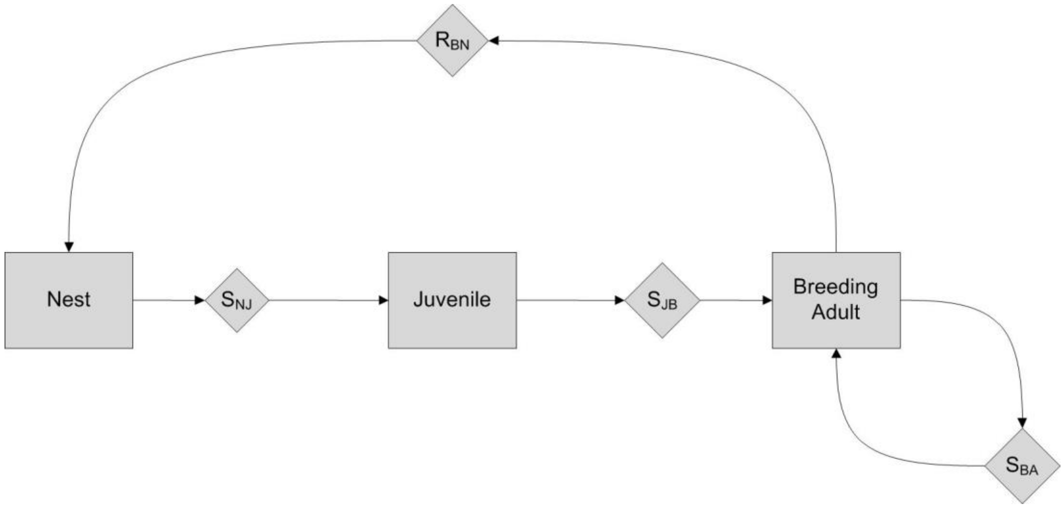

Figure 1.—Proposed YBCU life history model.
Squares indicate the life stage, and diamonds indicate the life-stage outcomes.
S_{NJ} = survivorship rate, nest; S_{JB} = survivorship rate, juveniles; S_{BA}= survivorship rate, breeding adults; and R_{BN} = reproduction rate, breeding adults.

Chapter 3 – Critical Biological Activities and Processes

Critical biological activities and processes consist of activities in which the species engages and biological processes that take place during each life stage that significantly shape the rate(s) of the outcome(s) for that life stage. Critical biological activities and processes are "rate" variables (i.e., the rate [intensity] of these activities and processes, taken together, determine the rate of recruitment of individuals from one life stage to the next).

The CEM identifies eight critical biological activities and processes that affect one or more YBCU life stages. Some of these activities or processes differ in their details among life stages. However, grouping biological activities or processes across all life stages into broad types makes it easier to compare the individual life stages to each other across the entire life cycle. Table 2 lists the eight critical biological activities and processes and their distribution across life stages.

Table 2.—Distribution of YBCU critical biological activities and processes among life stages
(Xs indicate that the critical biological activity or process is applicable to that life stage.)

Life stage ➔ / **Critical biological activity or process 🡻**	**Nest**	**Juvenile**	**Breeding adult**
Disease	X	X	X
Eating	X		
Foraging		X	X
Molt	X	X	X
Nest attendance			X
Nest site selection			X
Predation	X	X	X
Temperature regulation	X	X	X

The most widely used sources of the information used to identify the critical biological activities and processes are Laymon et al. (1997), Hughes (1999), Halterman (2002), McNeil et al. (2013b), Reclamation (2004, 2008), and BIO-WEST, Inc. (2005). These publications summarize and cite large bodies of earlier studies. Where appropriate and accessible, those earlier studies are directly cited. The identification also integrates information from both older and more recent works as well as the expert knowledge of LCR MSCP avian biologists. The following paragraphs discuss the eight critical biological activities and processes in alphabetical order.

DISEASE

This process refers to diseases caused either by lack of genetic diversity or by infectious agents. Little is known about disease prevalence or its effects on YBCU populations along the LCR. Although the more common avian diseases and parasites of North American birds are generally known (Morishita et al. 1999), some are often difficult to detect (Jarvi et al. 2002), and they can have differing effects on different species (Palinauskas et al. 2008). YBCU in all life stages are conceivably susceptible to disease. The U.S. Geological Survey (USGS) (USGS 2004 *in* U.S. Fish and Wildlife Service [USFWS] 2011) lists YBCU as a species affected by West Nile Virus.

EATING

This process only applies to the nest stage because nestlings must eat to stay alive and develop but do not actively forage within their environment in the same way as juveniles and adults. A nestling’s ability to eat is determined by the provisioning rate of its parents. (Juveniles are still fed by adults for some time after fledging (see the habitat element of parental feeding behavior).

FORAGING

YBCU are primarily gleaning insectivores, although they will also sally from a perch to catch insects on the wing (Hughes 1999; Reclamation 2008). Their primary diet is large insects, but they will sometimes take small vertebrates such as tree frogs (Anura) (Hughes 1999; Reclamation 2008). Foraging is done by juveniles and adults, but it is important to note that foraging by the parents affects the provisioning rate to nestlings and nest attendance by adults. In addition, juveniles may still be fed by adults for some time after fledging, decreasing their dependence on foraging.

MOLT

Nestling, juvenile, and adult YBCU must molt during their time along the LCR. Molting is an energetically costly process that may make nestlings more susceptible to death when resources are scarce (Howell 2010).

NEST ATTENDANCE

Both males and females participate in incubation and feeding young, with males most responsible for overnight roosting with nestlings (Halterman 1991; Hughes 1999). Nest attendance is performed by breeding adults (and is dependent in part on their survivorship) and affects the nest life stage (egg hatching and the provisioning rate to nestlings).

NEST SITE SELECTION

Both breeding males and females select a nest site (Halterman 1991; Hughes 1999). Nest site selection is important for reproductive success because nest success varies spatially (McNeil et al. 2013).

PREDATION

Predation is a threat to YBCU in all life stages, and it obviously affects survival. The predators of and rates of predation upon eggs and nestlings are much better understood (McNeil et al. 2013) than predation upon adults and juveniles, although it has been suggested that Cooper's hawks (*Accipiter cooperii*) may be the primary predator of adult YBCU (Reclamation 2008).

TEMPERATURE REGULATION

Temperature regulation is important for any organism inhabiting a region with temperatures as high as that of the LCR. Although overheating is possible during all life stages, most of the concern has been directed at eggs and nestlings (Hunter et al. 1987a, 1987b; Rosenberg 1991). Adults can affect the temperature regulation of eggs and nestlings through their own behavior (incubation or shading) and through nest placement.

Chapter 4 – Habitat Elements

Habitat elements consist of specific habitat conditions that ensure, allow, or interfere with critical biological activities and processes. Some elements, such as brood size and genetic diversity and infectious agents, are not traditionally considered aspects of habitat but are included in this section because of their effects on critical biological activities and processes. Similarly, anthropogenic disturbance is included as a habitat element, as it is a habitat characteristic that a cuckoo must contend with when nesting or foraging. Recreational activities are human actions that affect this habitat element and are considered to be a controlling factor.

This chapter identifies 19 habitat elements that affect 1 or more critical biological activities and processes across the 3 YBCU life stages. Some of these habitat elements differ in their details among life stages. For example, YBCU in different life stages experience different predation risks. However, using the same labels for the same *kinds* of habitat elements across all life stages makes comparison and integration of the CEMs for the individual life stages across the entire life cycle less difficult.

The habitat elements included here were chosen based upon scientific literature demonstrating a direct influence on YBCU, influence on similar species or species in similar habitats, or based upon the experience of the author and reviewers with YBCU or related species.

Table 3 lists the 19 habitat elements and the critical biological activities and processes that they *directly* affect across all YBCU life stages.

The most widely used sources of the information used to identify the habitat elements are Laymon et al. (1997), Hughes (1999), Halterman (2002), McNeil et al. (2013b), Reclamation (2004, 2008), and BIO-WEST, Inc. (2005). These publications summarize and cite large bodies of earlier studies. Where appropriate and accessible, those earlier studies are directly cited.

As with all tabulations of habitat associations, inferences that particular habitat characteristics are critical to a species or life stage require evidence and CEMs for why each association matters to species viability (Rosenfeld 2003; Rosenfeld and Hatfield 2006.)

The diagrams and other references to habitat elements elsewhere in this document identify the habitat elements by a one-to-three-word short name. However, each short name in fact refers to a longer, complete name. For example, “predator density” is the short name for “The abundance and distribution of species that depredate YBCU during the nest, juvenile, and breeding adult stages.” The following paragraphs provide the full name for each habitat element and provide a detailed definition, addressing the elements in alphabetical order.

Table 3.—Distribution of YBCU habitat elements and the critical biological activities and processes that they directly affect across all life stages
(Xs indicate that the habitat element is applicable to that critical biological activity or process.)

Critical biological activity or process ➔ / **Habitat element 🡻**	**Disease**	**Eating**	**Foraging**	**Molt**	**Nest attendance**	**Nest site selection**	**Predation**	**Temperature regulation**
Anthropogenic disturbance		X	X		X	X	X	
Brood size		X	X		X			
Canopy closure			X			X	X	X
Community type			X			X	X	
Diversity of vegetation			X			X		
Food availability			X					
Genetic diversity and infectious agents	X							
Humidity					X	X		X
Intermediate structure						X	X	X
Linear width of patch						X	X	
Local hydrology								
Matrix community			X			X		
Parental feeding behavior			X				X	
Parental nest attendance		X					X	X
Patch phenology			X			X		
Patch size						X	X	
Predator density					X	X	X	
Temperature					X	X		X
Tree density						X	X	

Note : There is no habitat element that *directly* affects molt. Local hydrology *indirectly* affects certain critical biological activities and process through effects on community type, food availability, humidity, and temperature around a nest.

ANTHROPOGENIC DISTURBANCE

Full name: **Human activity within or surrounding a given habitat patch, including noise, pollution, and other disturbances associated with human activity**. Whether due to recreational, land management, or scientific research activities, the presence of humans can disturb YBCU, causing changes in behavior that might ultimately affect survival. Anthropogenic noise can affect both the breeding success and survival of birds (reviewed by Barber et al. 2010; Francis and Barber 2013). Noise might mask conspecific cues such as songs or calls, making it more difficult for YBCU to attract or find mates. The effect of disturbance by the presence of humans is better described for other species but has also been documented for YBCU (USFWS 2011; McNeil et al. 2013). Anthropogenic disturbance is considered to be a habitat element, as it is an environmental characteristic or background condition with which a nesting or foraging cuckoo must contend.

BROOD SIZE

Full name: **The number of young in the nest**. This element refers to the number of young that the parents must rear per nest. Clutch size is related to maternal health, and the well-being of both parents depends in part on the availability of sufficient food resources in close proximity to the breeding territory (see Gill 2007 and references therein) as well as other factors such as predator density (see the "Predator Density" section below). In addition, the greater the number of young, the less food may be available for each, potentially affecting growth and survival of individual chicks (see Gill 2007 and references therein).

CANOPY CLOSURE

Full name: **The proportion of the sky hemisphere obscured by vegetation when viewed from a single point as measured with a spherical densitometer (Jennings et al. 1999)**. This element refers to the percent canopy closure of canopy vegetation in the vicinity of the YBCU nest site. Canopy cover of riparian vegetation, especially higher density in the upper canopy, has been shown to be important to YBCU (Laymon et al. 1997; Halterman 2004). Dense vegetation around the nest may provide more optimal microclimate for thermoregulation (Rosenberg 1991; McNeil at al. 2013b, but see Balluff 2012 for other discussion) and camouflage from nest predators, although heterogeneity in canopy cover within a given patch or landscape may also be desirable (see "Diversity of

Vegetation," below). Canopy cover may also affect the availability of food (Smith et al. 2006). Canopy cover is often related to tree density (James 1971; Rudnicki et al. 2004).

COMMUNITY TYPE

Full name: **The species composition of the riparian forest patch**. This element refers to the species composition of riparian habitat used for breeding by YBCU. Research shows the ideal habitat to be composed primarily of cottonwood (*Populus fremontii*) and willow (*Salix gooddingii*) (Gaines 1974; Laymon and Halterman 1989; Rosenberg 1991; McNeil et al. 2013). However, Laymon and Halterman (1989) also emphasize the importance of community type, stating that YBCU will occupy mesquite (*Prosopis* sp.) areas once cottonwood-willow habitats are saturated with nesting YBCU. In addition to influencing nest site selection, community type also affects invertebrate diversity and nutrient content (Wiesenborn 2014).

DIVERSITY OF VEGETATION

Full name: **Either horizontal or vertical diversity of the vegetation structure at the patch or microhabitat scales or diversity of community types at the landscape scale**. The diversity of vegetation affects site use by many animals (MacArthur and MacArthur 1961; Erdelen 1984; Wiens et al. 1993). YBCU prefer sites with dense shrub and canopy cover, which likely have high foliage height diversities and leaf area indices. McNeil et al. (2013b) found that nest placement by YBCU was positively associated with canopy closure at all layers, indicating a preference for areas with increased foliage height diversity. Horizontal diversity—or variation in vegetation density within a patch—also has been shown to positively affect site use by YBCU (Johnson et al. 2012). Johnson et al (2012) suggest that, at a landscape scale, YBCU avoid sites surrounded by a high diversity of vegetation types—a measure of habitat fragmentation. However, McNeil et al. (2013b) state that a mosaic of stands in different seral stages would fulfill both the nesting and foraging needs of YBCU.

FOOD AVAILABILITY

Full name: **The abundance of food available for adults and their young**. This element refers to the taxonomic and size composition of the invertebrates that an individual YBCU will encounter during each life stage as well as the density and spatial distribution of the food supply in proximity to the nest. Cuckoos primarily feed on larger bodied insects such as caterpillars, cicadas, and katydids (Laymon

1980 *in* Hughes 1999), and in some areas of their range, their nesting activity coincides with cicada emergences (Hughes 1999), making both the density and phenology of cicada emergence important for YBCU in the Southwestern United States. The abundance and condition of the food supply affects adult health and the growth and development of the young during the nest and juvenile stages.

GENETIC DIVERSITY AND INFECTIOUS AGENTS

Full name: **The genetic diversity of YBCU individuals and the types, abundance, and distribution of infectious agents and their vectors**. The genetic diversity component of this element refers to the genetic homogeneity versus heterogeneity of a population during each life stage. The greater the heterogeneity, the greater the possibility that individuals of a given life stage will have genetically encoded abilities to survive their encounters with the diverse stresses presented by their environment and/or take advantage of the opportunities presented (Allendorf and Leary 1986). The infectious agent component of this element refers to the spectrum of viruses, bacteria, fungi, and parasites that individual YBCU are likely to encounter during each life stage. Hughes (1999) lists several parasites known to affect individual YBCU, although Wiggins (2005) suggests the magnitude of the effects are unknown.

HUMIDITY

Full name: **The amount of moisture in a habitat patch or nest site**. This element refers to the average relative humidity in the nesting habitat. Higher humidity levels may reduce the potential for egg desiccation and thermal stress and is important for egg and nestling survival in the more arid landscapes of the LCR region (McNeil et al. 2013). Humidity at YBCU nest sites along the LCR is related to canopy closure and local hydrology (McNeil et al. 2013).

INTERMEDIATE STRUCTURE

Full name: **The concealment provided by the vegetation structure between the canopy and the herbaceous (=ground) layer**. This element refers to the visual density of vegetation (i.e., concealment) below the uppermost canopy layer. This has been shown to be a factor in YBCU nest site selection (Gaines 1974; Gaines and Laymon 1984; Halterman and Laymon 1994; McNeil et al. 2013). A more dense intermediate structure may support a more diverse and abundant invertebrate food supply as well as provide protection or camouflage from predators.

LINEAR WIDTH OF PATCH

Full name: **The width of a patch of riparian habitat**. This element refers to the width of riparian habitat along a corridor. Habitat width has been shown to influence cuckoo distribution and abundance (Gaines 1974), with wider habitat patches supporting cuckoo breeding. Patch width may also affect the presence of nest parasites and other predators.

LOCAL HYDROLOGY

Full name: **Aspects such as the distance to standing water or the presence of adjacent water bodies, timing and volume of floods, depth to the water table, and soil moisture levels**. This element refers to anything that affects soil moisture, such as the proximity of water to the nesting habitat, elevation, irrigation practices, and soil texture. Western YBCU are riparian obligates (Hunter et al. 1987b), typically found within 100 meters of water (Gaines 1974). The presence of moist soil or standing water affects food availability (e.g., supporting more and a greater diversity of invertebrates) and may provide cooler temperatures and more humid conditions that are necessary for egg and chick survival in these desert systems (Hunter et al. 1987a, 1987b; Laymon and Halterman 1987; Balluff 2012; McNeil et al. 2013).

MATRIX COMMUNITY

Full name: **The type of habitat surrounding riparian patches used by cuckoos**. This element refers to the types of plant communities and land-use activities surrounding riparian habitat patches used by YBCU. Halterman (1991) found no evidence of an influence of a surrounding matrix on the selection of breeding habitat by YBCU. However, YBCU will use orchards planted outside of riparian areas and have been observed foraging within mesquite areas surrounding riparian forests (Halterman 2002; McNeil et al. 2013). Further, Laymon and Halterman (1989) state that YBCU will occupy mesquite areas once cottonwood-willow habitats are saturated with nesting YBCU. McNeil et al. (2013b) recommend the preservation of existing mesquite areas in part because they are occasionally used for nesting. Mesquite and other flowering shrubs also provide habitat for diverse insect species (B. Raulston 2014, personal communication).

PARENTAL FEEDING BEHAVIOR

Full name: **The ability and behavior of parents to feed and care for juveniles after they fledge from the nest**. This element refers to the capacity of both parents to provision food for recently fledged birds. Juveniles are dependent on adults for food for 2 weeks (Laymon and Halterman 1985), although adults may feed the young for 3 to 4 weeks after fledging (Halterman 1991; McNeil et al. 2013). The feeding rate is dependent upon food availability and the number of young in the brood. This rate influences the amount of food and time spent foraging by juvenile birds and thus juvenile survival.

PARENTAL NEST ATTENDANCE

Full name: **The ability of both parents to care for young during the egg/incubation and nestling stages**. This element refers to the capacity of both parents to share nesting and brood-rearing responsibilities until fledging. It is affected by food availability, the presence of predators and competitors, and the ability to thermoregulate.

PATCH PHENOLOGY

Full name: **The seasonal timing of changes in vegetation structure due to monsoons or irrigation**. The timing and intensity of changes in the vegetation structure of a given patch of riparian forest are affected by the spatial and temporal variation in seasonal monsoons (Wallace et al. 2013). This seasonal and spatial variation of "greening up" affects site use by YBCU (Wallace et al. 2013).

PATCH SIZE

Full name: **The size of riparian habitat patches**. This element refers to the area of a given patch of riparian vegetation. Patch size affects the number of breeding pairs that an area can support (Laymon and Halterman 1989; Launer et al. 1990; Halterman 2002; Halterman et al. 2009; McNeil et al. 2013) as well as the density of predators.

PREDATOR DENSITY

Full name: **The abundance and distribution of species that depredate YBCU during the nest, juvenile, and breeding adult stages**. This element refers to a set of closely related variables that affect the likelihood that different kinds of predators will encounter and successfully prey on YBCU during any life stage. The variables of this element include the species and size of the fauna that prey on YBCU during different life stages, the density and spatial distribution of these fauna in the riparian habitat used by cuckoos, and the ways in which predator activity may vary in relation to other factors (e.g., intermediate structure, matrix community type, patch size and width, time of day, vegetation diversity, etc.) (Thompson, III 2007).

The effect of predator density can have impacts more subtle than survival by altering YBCU breeding behavior, foraging behavior, and nest site selection (Lima 1998, 2009).

TEMPERATURE

Full name: **The mean temperature in a habitat patch or nest site**. This element refers to the average temperature in the nesting habitat around the nest site (or during the nesting season). High temperatures typical of the LCR region in the summer can kill eggs and stress young in the nest (Hunter et al. 1987b; Rosenberg 1991). The temperature at YBCU nest sites along the LCR is related to canopy closure and local hydrology (McNeil et al. 2013).

TREE DENSITY

Full name: **The stem density of trees reported as the number of trees per acre**. The greater the tree and/or shrub density, the greater the likelihood of denser vegetative cover. Tree density may also affect invertebrate density. For example, at one location (along the Middle Rio Grande, New Mexico), cicada density was higher in areas with a higher tree density of cottonwoods (Smith et al. 2006). However, this may not apply in all locations and for other invertebrate species on which YBCU feed – more research is needed. Further, YBCU may use basal area as a criterion for site selection (Laymon et al. 1997).

Chapter 5 – Controlling Factors

Controlling factors consist of environmental conditions and dynamics, both natural and anthropogenic, which affect the abundance, spatial and temporal distributions, and quality of critical habitat elements. These may also significantly directly affect some critical biological activities and processes. A hierarchy of such factors exists, with long-term dynamics of climate and geology at the top. However, this CEM focuses on nine immediate controlling factors that are within the scope of potential human manipulation. The nine controlling factors identified in this CEM do not constitute individual variables; rather, each identifies a category of variables (including human activities) that share specific features, which makes it useful to treat them together. Table 4 lists the nine controlling factors and the habitat elements they directly affect. Table 4 also shows nine habitat elements that are not directly affected by any controlling factor (brood size, diversity of vegetation, genetic diversity and infectious agents, humidity, parental feeding behavior, parental nest attendance, patch phenology, temperature). These latter habitat elements are directly shaped by the condition of one or more other habitat elements rather than by any of the controlling factors.

Table 4.—Habitat elements directly affected by controlling factors

Controlling factor ➔ **Habitat element 🡻**	**Fire management**	**Grazing**	**Mechanical thinning**	**Natural thinning**	**Nuisance species introduction and management**	**Pesticide/herbicide application**	**Planting regime**	**Recreational activities**	**Water storage-delivery system design and operation**
Anthropogenic disturbance			X					X	
Brood size	N/A								
Canopy closure	X		X	X	X		X	X	
Community type	X	X			X		X	X	X
Diversity of vegetation	N/A								
Food availability					X	X			
Genetic diversity and infectious agents	N/A								
Humidity	N/A								
Intermediate structure	X	X	X		X		X	X	
Linear width of patch	X	X					X	X	
Local hydrology									X
Matrix community	X	X					X		
Parental feeding behavior	N/A								
Parental nest attendance	N/A								
Patch phenology	N/A								
Patch size	X	X					X	X	
Predator density								X	
Temperature	N/A								
Tree density	X		X	X	X		X	X	

FIRE MANAGEMENT

This factor addresses any fire management (whether prescribed fire or fire suppression) that could affect YBCU or their habitat. Effects may include creation of habitat that supports or excludes YBCU, a reduction in the food supply of invertebrates with soil stage (katydids, sphinx moths [Sphingidae], cicadas) affected by hot fire (Smith et al. 2006), or support of species that pose threats to YBCU such as predators, competitors, or carriers of infectious agents. Although typically not a major threat in most riparian habitats, severe wildfires have affected southwestern willow flycatcher breeding sites in the past decade (USFWS 2002a; Graber et al. 2007; Ellis et al. 2001) and could affect YBCU riparian habitats along the LCR similarly. In fact, severe fires have recently occurred in a few LCR restoration sites (Hunter's Hole and Yuma East Wetlands) and in riparian habitat at the Havasu National Wildlife Refuge (C. Dodge 2015, personal communication). Climate change is also projected to affect fire frequency along the LCR (USFWS 2013).

GRAZING

This factor addresses the grazing activity on riparian habitats along the LCR and in surrounding areas that could affect YBCU or their habitat. Grazing by cattle (Bovidae), burros (*Equus asinus*), or mule deer (*Odocoillllllleus hemionus*) across the arid Southwestern United States has substantially degraded riparian habitat (see Appendix G *in* USFWS 2002b). (Note: Reclamation staff and researchers have observed mule deer browsing on LCR sites, which may become an issue if populations are not managed). Grazing may thin the understory or even prevent the establishment of cottonwood and willow seedlings (Kauffman et al. 1997). Krueper (1993) and Krueper et al. (2003) report that fencing cattle out of sensitive riparian habitats in the San Pedro Riparian National Conservation Area led to improved habitat quality and increased riparian bird density within 4 years. Livestock grazing is also known to occur at the Gila River study area (Graber et al. 2012). Further, the USFWS (2011) discusses potential effects of grazing on YBCU, and both Arizona (Latta et al. 1999) and Utah Partners in Flight (Parrish et al. 2002) recommend reducing grazing near riparian zones as a management action for YBCU.

Grazing activity may also influence other controlling factors, such as nuisance species introduction and management, by increasing cowbird (*Molothrus ater*) presence or by spreading non-native grass seeds into riparian habitat (Goguen and Mathews 2001; Bartuszevige and Endress 2008; Tucson Audubon 2012).

MECHANICAL THINNING

This factor addresses the active removal of vegetation from areas within the LCR region. Effects may include creation of habitat that supports or excludes YBCU or support of species that pose threats to YBCU such as predators, competitors, or carriers of infectious agents. This factor includes the thinning of vegetation within both the riparian and matrix communities. Thinning can be implemented on a small local scale, resembling natural thinning, or can be implemented on a broad scale with larger and more complete transition. Mechanical thinning always increases the level of anthropogenic disturbance, especially noise, within the habitat.

NATURAL THINNING

This factor addresses the natural death of trees within a patch of riparian forest or the surrounding matrix. As overstory trees die, they leave openings in the canopy, thereby allowing light to reach lower vegetation layers and creating the horizontal and vertical foliage profiles needed by YBCU. This structural complexity may increase food availability.

NUISANCE SPECIES INTRODUCTION AND MANAGEMENT

This factor addresses the intentional or unintentional introduction of nuisance species (animals and plants) and their control that affects YBCU survival and reproduction. Nuisance species may infect, prey on, compete with, or present alternative food resources for YBCU during one or more life stages; cause other alterations to the riparian food web that affect YBCU; or affect physical habitat features such as canopy or understory density. For example, sites dominated by invasive tamarisk (*Tamarix* sp.) are generally considered as poor quality nesting habitat for YBCU (Gaines and Laymon 1984; Corman and Magill 2000; USFWS 2011; Johnson et al. 2012; McNeil et al. 2013).

PESTICIDE/HERBICIDE APPLICATION

This factor addresses biocide applications that may occur on or adjacent to riparian habitat of the LCR region. The effects may include sublethal poisoning of YBCU via ingestion of treated insects, pollution of runoff into wetland habitats that are toxic to prey of YBCU, or a reduced invertebrate food supply (Laymon and Halterman 1987). The USFWS (2011) discusses the issue of effects of pesticides/herbicides on YBCU and states that the issue warrants further study.

PLANTING REGIME

This factor addresses the active program to restore cottonwood-willow riparian habitat along the LCR and includes both the community planted as well as the manner in which it is planted within restoration areas (e.g., density, age, and patch size). Restoration areas are generally successful in providing habitat for YBCU (Rosenberg 1991; McNeil et al. 2013).

RECREATIONAL ACTIVITIES

This factor addresses the disturbance to YBCU from recreational activities. Even non-consumptive human activity can have negative effects on wildlife (reviewed by Boyle and Samson [1985]). This is a broad category that encompasses the types of activity (e.g., boating, fishing, horseback riding, and camping) as well as the frequency and intensity of those activities. The impacts may consist of direct disturbance to YBCU and habitat alteration. Recreational activities can influence nest-predator densities by either increasing predator success rates through interfering with or distracting prey or by decreasing predator success rates through interfering with or distracting the predator (Mason 2015; Ware et al. 2015). Specific activities such as hunting may be affecting YBCU populations (McNeil et al. 2013). In fact, both Arizona (Latta et al. 1999) and Utah Partners in Flight (Parrish et al. 2002) recommend reducing recreational activities near riparian zones as a management action for YBCU.

Additionally, intensive research and monitoring that regularly disturbs nesting birds may adversely affect nest success. The impacts will depend on the tolerance of the bird species in question, predators and brood parasites present in the habitat, the frequency and type of nest disturbance, and other factors. However, precautionary measures should be included in the design of monitoring protocols until more is known about the potential effects of research-related disturbance on nesting YBCU.

WATER STORAGE-DELIVERY SYSTEM DESIGN AND OPERATION

Much of the habitat currently used by YBCU within the LCR area is along regulated waterways. The water moving through this system is highly regulated for storage and delivery (diversion) to numerous international, Federal, State, Tribal, and municipal users and for hydropower generation. In contrast, the dynamic nature of a free-flowing river creates an mosaic of riparian habitats, and thus, a natural flow regime may be beneficial to YBCU (Launer et al. 1990; Halterman and Laymon 1994).

Chapter 6 – Conceptual Ecological Model by Life Stage

This chapter contains three sections, each presenting the CEM for a single YBCU life stage. The text and diagrams identify the critical biological activities and processes for each life stage, the habitat elements that support or limit the success of these critical biological activities and processes, the controlling factors that determine the abundance and quality of these habitat elements, and the causal links among them. The CEM sections specifically refer to the river and lakes of the LCR and other protected areas managed as YBCU habitat and thus address this landscape as a whole rather than any single reach or managed area.

The CEM for each life stage assesses the character and direction, magnitude, predictability, and scientific understanding of each causal link based on the following definitions (see attachment 1 for further details):

- **Character and direction** categorizes a causal relationship as positive, negative, or complex. "Positive" means that an increase in the causal node results in an increase in the affected node, while a decrease in the causal node results in a decrease in the affected node. "Negative" means that an increase in the causal node results in a decrease in the affected element, while a decrease in the causal node results in an increase in the affected node. Thus, "positive" or "negative" here do ***not*** mean that a relationship is beneficial or detrimental. The terms instead provide information analogous to the sign of a correlation coefficient. "Complex" means that there is more going on than a simple positive or negative relationship. Positive and negative relationships are further categorized based on whether they involve any response threshold in which the causal agent must cross some value before producing an effect. In addition, the "character and direction" attribute categorizes a causal relationship as uni- or bi-directional. Bi-directional relationships involve a reciprocal relationship in which each node affects the other.

- **Magnitude** refers to "…the degree to which a linkage controls the outcome *relative to other drivers*" (DiGennaro et al. 2012). Magnitude takes into account the spatial and temporal scale of the causal relationship as well as the strength (intensity) of the relationship at any single place and time. The present methodology separately rates the intensity, spatial scale, and temporal scale of each link on a three-part scale from "Low" to "High" and assesses overall link magnitude by averaging the ratings for these three. If it is not possible to estimate the intensity, spatial scale, or temporal scale of a link, the subattribute is rated as "Unknown" and ignored in the averaging. If all three subattributes are "Unknown," however, the overall link magnitude is rated as "Unknown." Just as the terms for link character provide information analogous to the sign of a correlation coefficient, the terms for link magnitude provide information analogous to the size of a correlation coefficient.

- **Predictability** refers to "…the degree to which current understanding of the system can be used to predict the role of the driver in influencing the outcome. Predictability … captures variability… [and recognizes that] effects may vary so much that properly measuring and statistically characterizing inputs to the model are difficult" (DiGennaro et al. 2012). A causal relationship may be unpredictable because of natural variability in the system or because its effects depend on the interaction of other factors with independent sources for their own variability. Just as the terms for link character provide information analogous to the sign of a correlation coefficient, the terms for link predictability provide information analogous to the size of the range of error for a correlation coefficient. The present methodology rates the predictability of each link on a three-part scale from "Low" to "High." If it is not possible to rate predictability due to a lack of information, then the link is given a rating of "Unknown" for predictability.

- **Scientific understanding** refers to the degree of agreement represented in the scientific literature and among experts in understanding how each causal relationship works—its character, magnitude, and predictability. Link predictability and understanding are independent attributes. A link may be highly predictable but poorly understood or poorly predictable but well understood. The present methodology rates the state of scientific understanding of each link on a three-part scale from "Low" to "High."

The CEM for each life stage thus identifies the causal relationships that most strongly support or limit life-stage outcomes, support or limit the rate of each critical biological activity or process, and support or limit the quality of each habitat element, as that element affects other habitat elements or affects critical biological activities or processes.

A separate spreadsheet is used to record the assessment of the character and direction, magnitude, predictability, and scientific understanding for each causal link along with the underlying rationale and citations for each life stage. The CEM for each life stage, as cataloged in its spreadsheet, is illustrated with diagrams showing the controlling factors, habitat elements, critical biological activities and processes, and causal links identified for that life stage. A diagram may also visually display information on the character and direction, magnitude, predictability, and/or scientific understanding of every link. The diagrams use a common set of conventions for identifying the controlling factors, habitat elements, critical biological activities and processes, and life-stage outcomes as well as for displaying information about the causal links. Figure 2 illustrates these conventions.

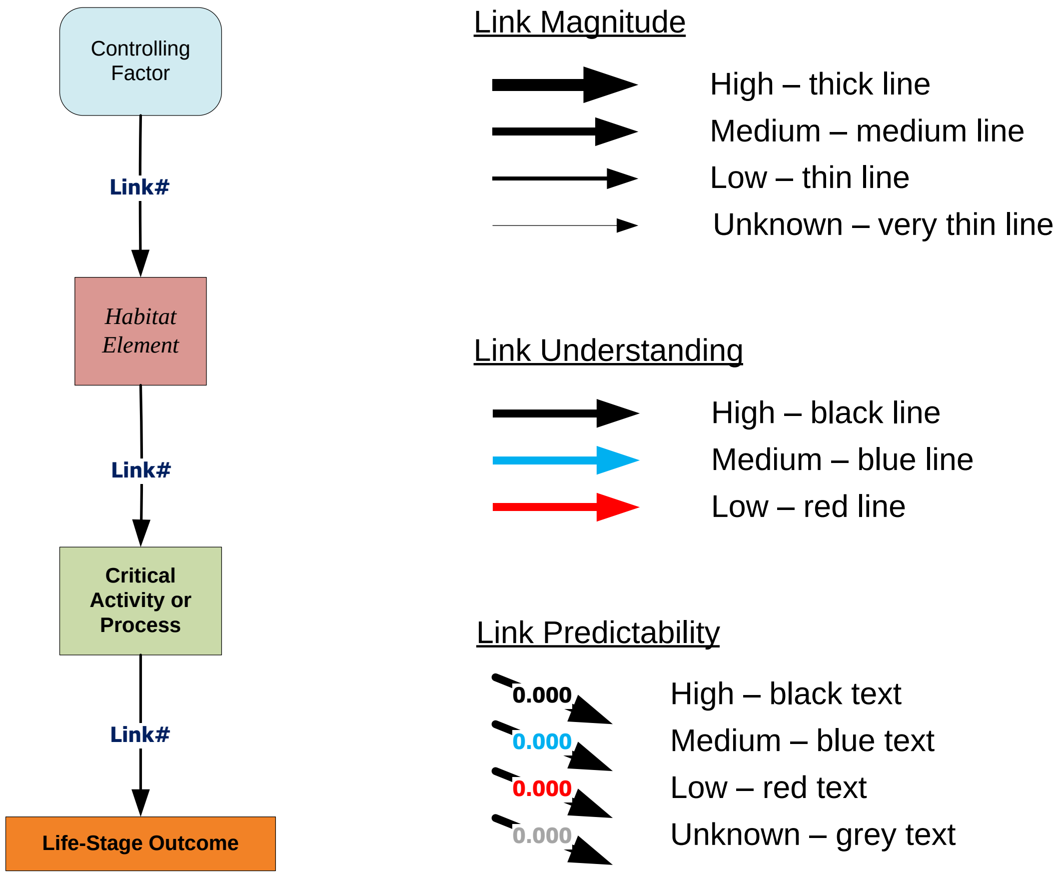

Figure 2.—Diagram conventions for LCR MSCP conceptual ecological models.

The discussion of each life stage includes an analysis of the information contained in the spreadsheet. The analyses highlight causal chains that strongly affect survivorship, identify important causal relationships with different levels of predictability, and identify important causal relationships with high scientific uncertainty. The latter constitutes topics of potential importance for adaptive management investigation.

The causal relationships between controlling factors and habitat elements are essentially identical across all three life stages. For this reason, the discussion of controlling factor-habitat element linkages across all three life stages appears in a subsequent chapter.

The causal relationships between controlling factors and habitat elements are essentially identical across all three life stages. For this reason, the discussion of controlling factor-habitat element linkages across all three life stages appears in a subsequent chapter.

YBCU LIFE STAGE 1 – NEST

The nest stage lasts from when the egg is laid until either the young fledge or the nest fails. Success during this life stage – successful transition to the juvenile stage – involves organism survival, maturation, molt, and fledging. The organisms actively interact with their environment.

The CEM (figures 3 and 4) recognizes five (of eight) critical biological activities and processes for this life stage. Not included are foraging, nest attendance, and nest site selection, as they are not part of the nest life stage. The critical biological processes and activities are presented here, ordered as they appear on the following figures.

1. **Disease** – Although the literature does not emphasize disease as affecting population levels of YBCU, we still feel that disease bears mentioning. Diseases and parasites are prevalent in avian populations, so it is safe to assume they have an impact on YBCU (Morishita et al. 1999). Disease and parasite impacts along the LCR is recommended as an area of potential research.

   The CEM recognizes genetic diversity and infectious agents as a habitat element affecting disease.

2. **Eating** – The nestling must eat to maintain metabolic processes.

   The CEM recognizes disease as the critical biological activity and process affecting eating, as does the habitat element of parental nest attendance.

3. **Predation** – Predation affects the survival of a nest.

   The CEM recognizes anthropogenic disturbance, canopy closure, community type, diversity of vegetation, intermediate structure, linear width of patch, parental nest attendance, patch size, predator density, and tree density as habitat elements affecting nest predation.

4. **Temperature Regulation** – The eggs and nestlings must maintain an optimum temperature to develop and survive.

   The CEM recognizes canopy closure, humidity, intermediate structure, parental nest attendance, and temperature as primary habitat elements directly affecting temperature regulation. The only critical biological activity and process having a direct impact on temperature regulation is disease.

5. **Molt** – The nestling must molt into juvenile plumage.

   The CEM recognizes the critical biological activities and processes of disease and eating as influencing molt. The CEM does not recognize any habitat elements as directly affecting molt.

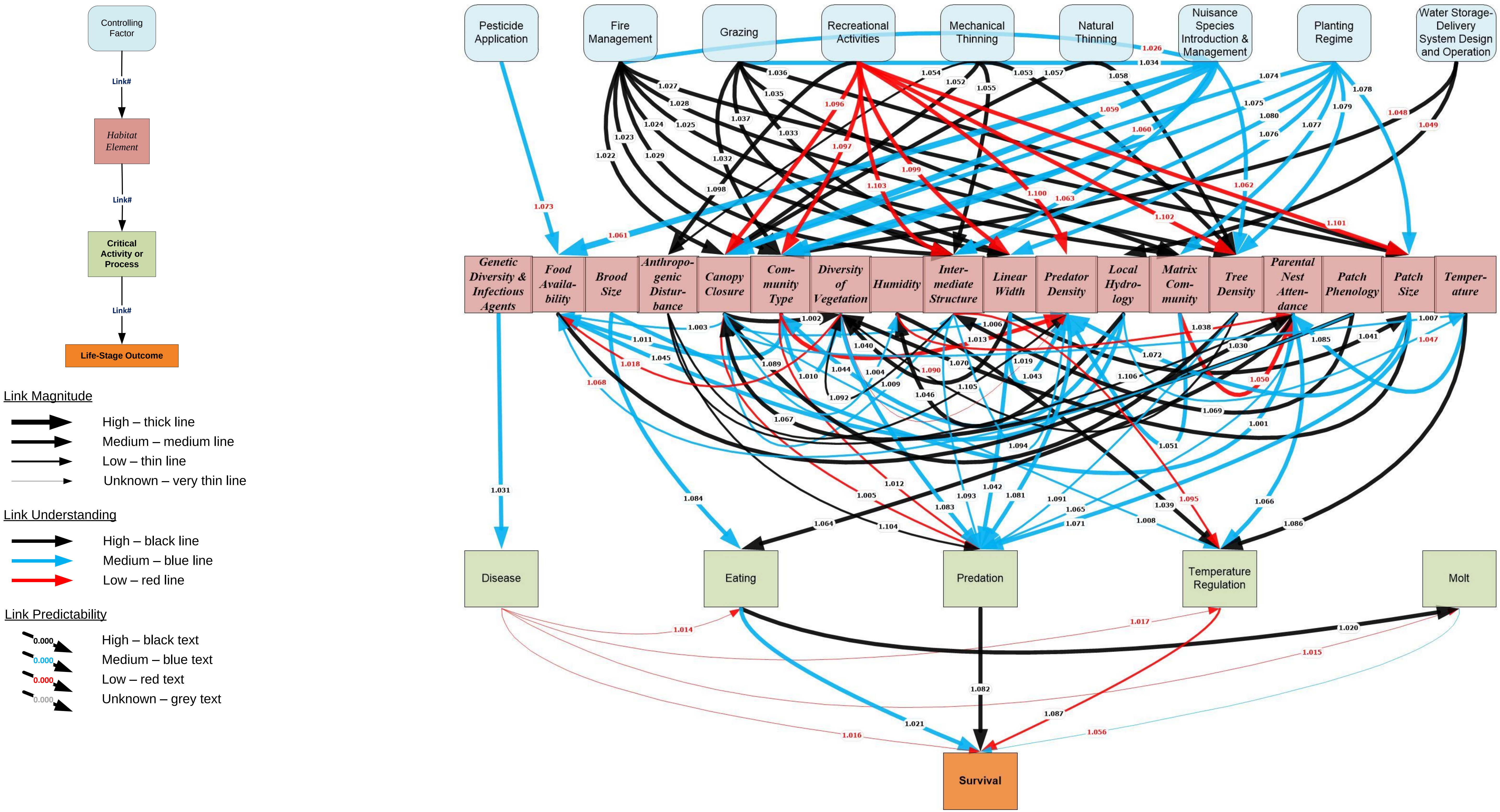

Figure 3.—YBCU life stage 1 – nest, basic CEM diagram showing the relevant controlling factors, habitat elements, and critical biological activities and processes at this life stage.

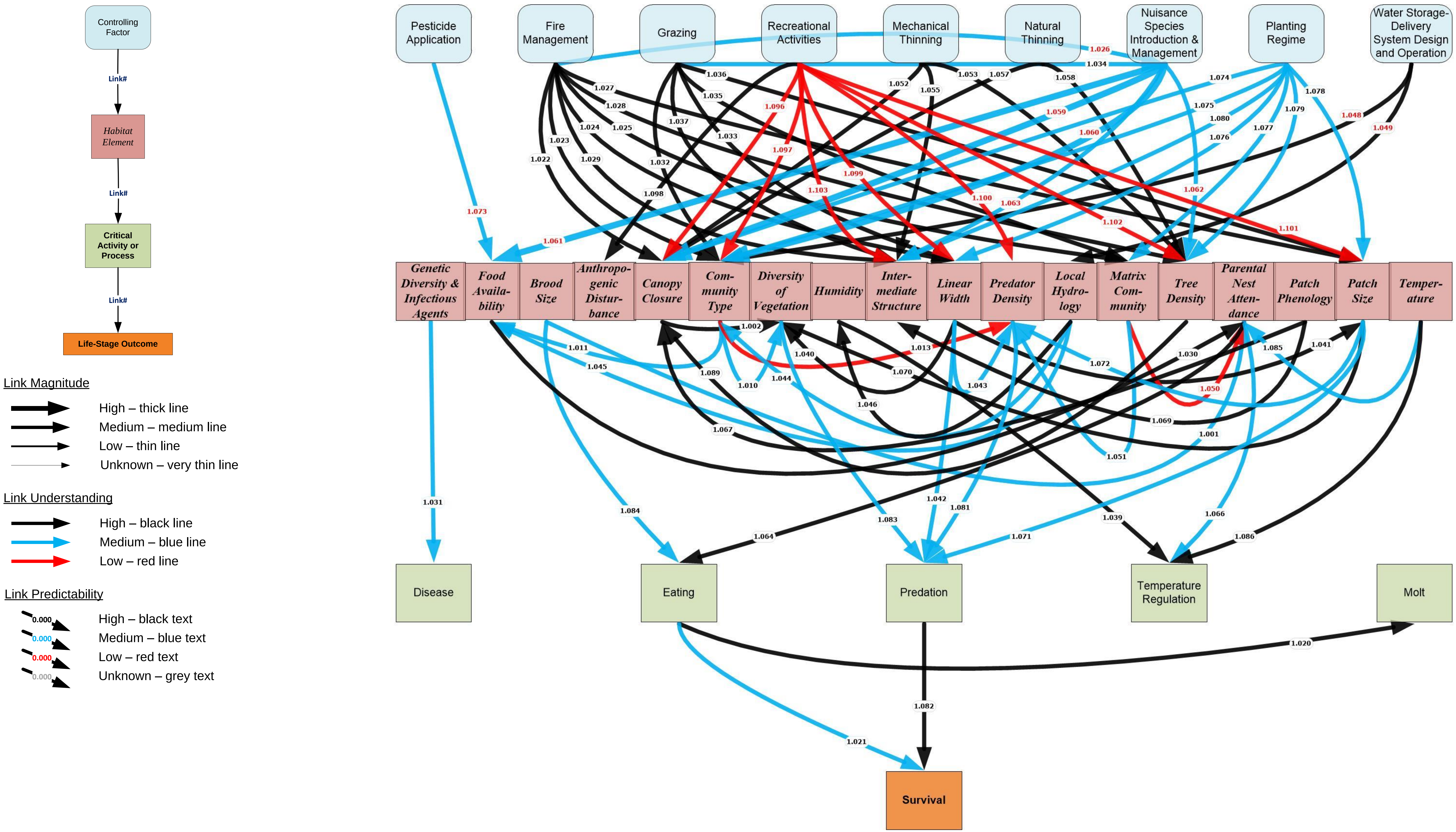

Figure 4.—YBCU life stage 1 – nest, high- and medium-magnitude relationships showing the relevant controlling factors, habitat elements, and critical biological activities and processes at this life stage.

YBCU LIFE STAGE 2 – JUVENILE

The juvenile stage begins at fledging and ends when the bird returns to the breeding grounds the next year. However, for the sake of this analysis, we will only emphasize the period between fledging and departure during autumn migration.

Success during this life stage – successful transition to the next stage – involves organism survival and maturation. The organisms actively interact with their environment.

The CEM (figures 5 and 6) recognizes five (of eight) critical biological activities and processes for this life stage. Eating, nest attendance, and nest site selection are not included, as they are part of other life stages. The critical biological processes and activities are presented here, ordered as they appear on the following figures.

1. **Disease** – Although the literature does not emphasize disease as affecting population levels of YBCU, we still feel that disease bears mentioning. Diseases and parasites are prevalent in avian populations, so it is safe to assume they have an impact on YBCU (Morishita et al. 1999). Disease and parasite impacts along the LCR is recommended as an area of potential research.

   The CEM recognizes genetic diversity and infectious agents as a habitat element affecting disease.

2. **Foraging** – Although still fed by the adult parents, the juvenile can now also forage for its own food in order to eat and maintain metabolic processes.

   The CEM recognizes anthropogenic disturbance, canopy closure, community type, diversity of vegetation, food availability, parental feeding behavior, the matrix community, and patch phenology as habitat elements affecting foraging. Foraging is directly affected by the critical biological activity and process of disease.

3. **Predation** – Predation directly affects survival.

   The CEM recognizes anthropogenic disturbance, canopy closure, community type, intermediate structure, linear width of patch, parental feeding behavior, patch size, predator density, and tree density as habitat elements directly affecting predation rates.

4. **Temperature Regulation** – The juvenile must maintain an optimum temperature to survive.

   The CEM recognizes canopy closure, humidity, intermediate structure, and temperature as habitat elements directly affecting temperature regulation. Disease as a critical biological activity and process can have influences on temperature regulation.

5. **Molt** – The juvenile must molt into basic plumage, and the process begins on the breeding grounds. Molt affects survival.

   The CEM does not recognize any habitat elements as directly affecting molt but many do indirectly through their impacts on foraging and eating.

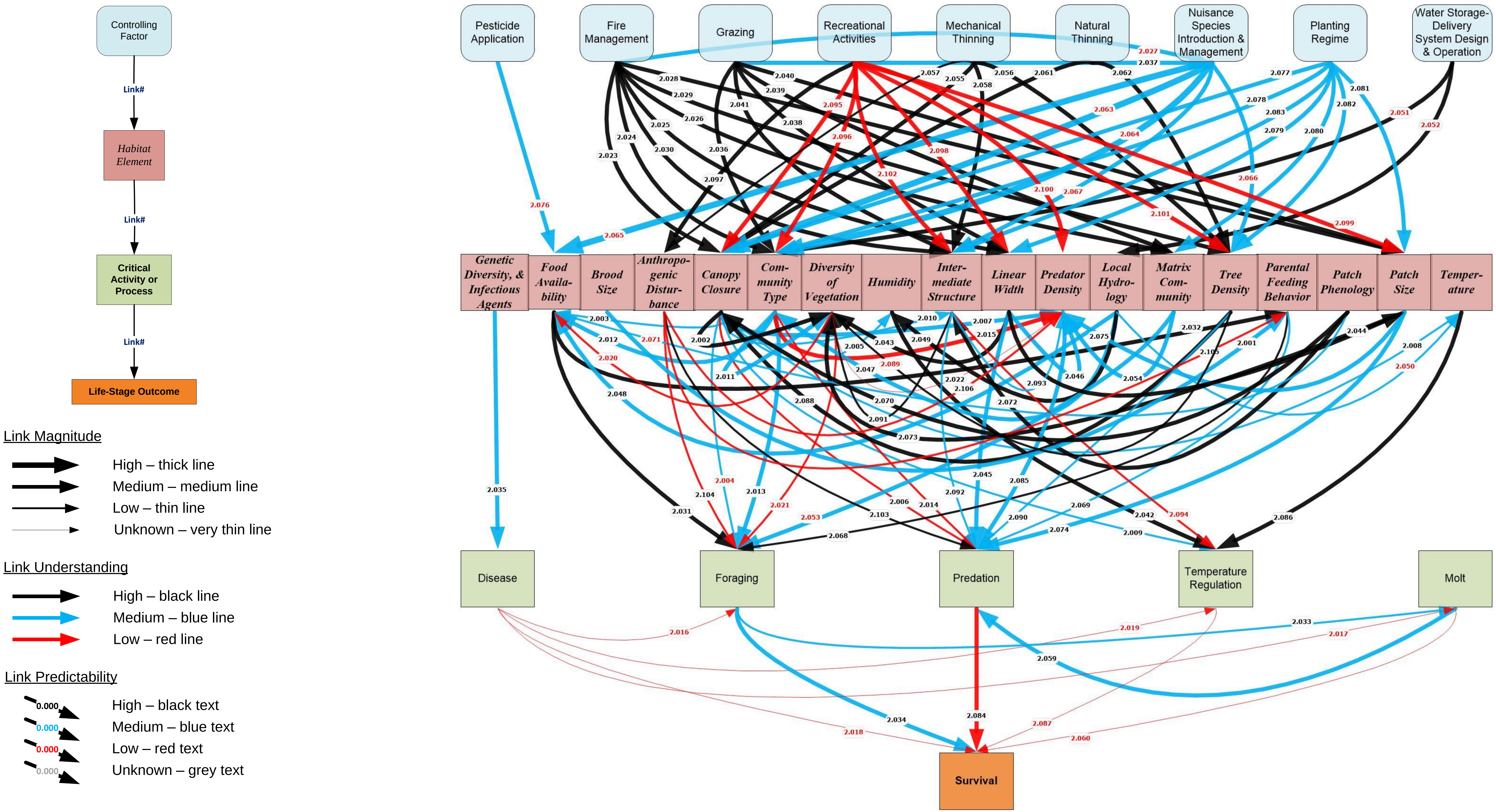

Figure 5.—YBCU life stage 2 – juvenile, basic CEM diagram showing the relevant controlling factors, habitat elements, and critical biological activities and processes at this life stage.

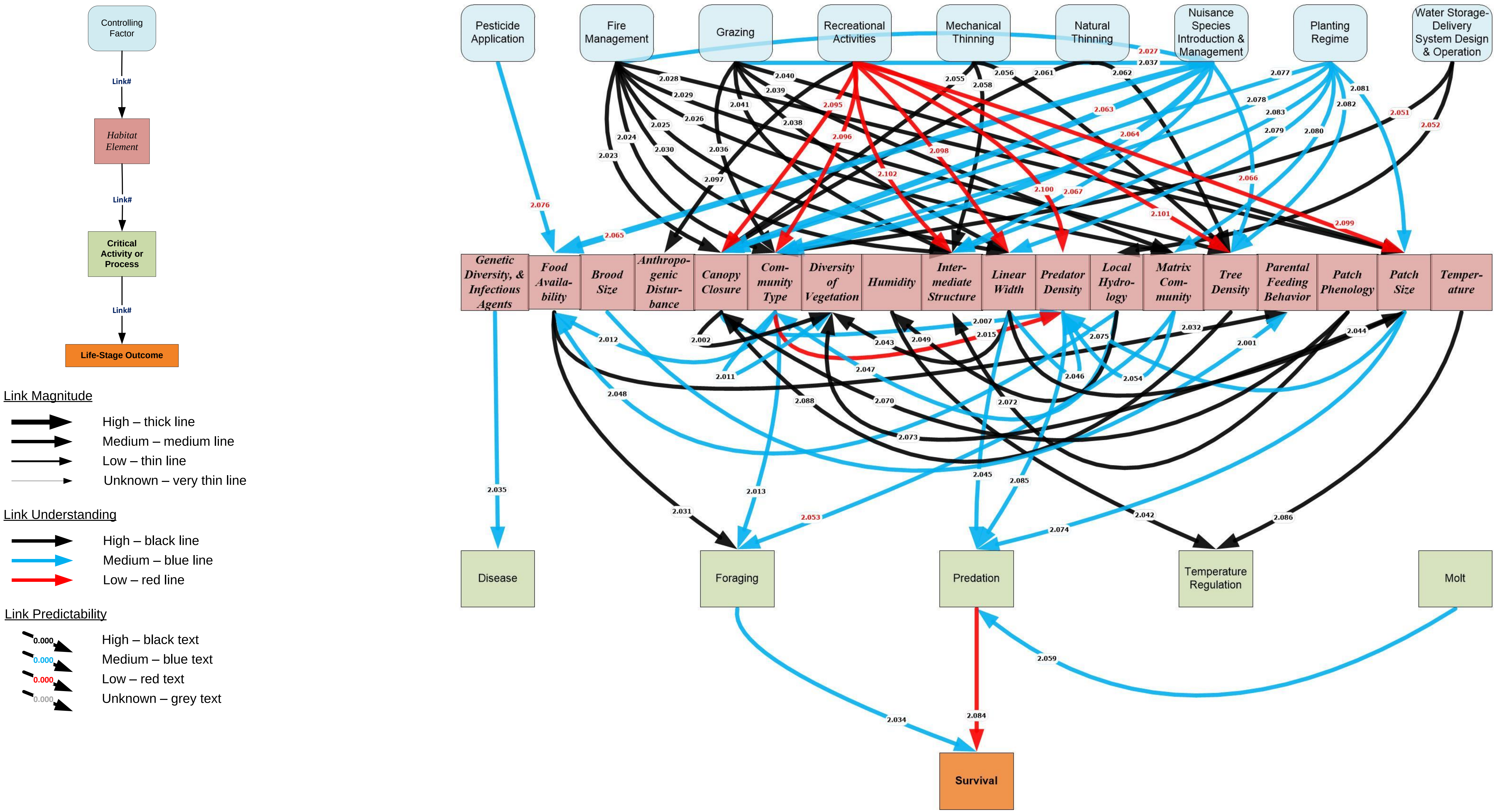

Figure 6.—YBCU life stage 2 – juvenile, high- and medium-magnitude relationships showing the relevant controlling factors, habitat elements, and critical biological activities and processes at this life stage.

YBCU LIFE STAGE 3 – BREEDING ADULT

The breeding adult stage begins when the bird returns to the breeding grounds after its first or subsequent winter and ends when it departs the breeding grounds during fall migration. Success during this life stage – successful transition to the next stage – involves organism survival and breeding. Individuals that do not successfully find a territory, floaters, are also included in this category even though they do not breed. The organisms actively interact with their environment.

The CEM (figures 7 and 8) recognizes seven (of eight) critical biological activities and processes for this life stage. Eating is not included as it is part of the nest life stage. The critical biological processes and activities are presented here, ordered as they appear on the following figures.

1. **Disease** – Although the literature does not emphasize disease as affecting population levels of YBCU, we still feel that disease bears mentioning. Diseases and parasites are prevalent in avian populations, so it is safe to assume they have an impact on YBCU (Morishita et al. 1999). Disease and parasite impacts along the LCR is recommended as an area of potential research.

   The CEM recognizes genetic diversity and infectious agents as a habitat element affecting disease.

2. **Foraging** – The breeding adult must forage to feed itself and its young. Both their survival and their young are dependent upon the foraging rate, which can be influenced by a number of factors.

   The CEM recognizes anthropogenic disturbance, brood size, canopy closure, community type, diversity of vegetation, food availability, the matrix community, and patch phenology as habitat elements directly affecting foraging. Disease is a critical biological activity and process that also directly affects foraging.

3. **Predation** – Adults must avoid predation to survive.

   The CEM recognizes anthropogenic disturbance, canopy cover, community type, linear width of patch, patch size, predator density, and tree density as habitat elements affecting predation. There are no critical biological activities and processes that directly affect predation.

4. **Nest Site Selection** – The breeding adult must choose where to place the nest, as nest placement will affect breeding success.

   The CEM recognizes anthropogenic disturbance, canopy closure, community type, diversity of vegetation, humidity, intermediate structure, linear width of patch, the matrix community, patch phenology, patch size, predator density, temperature, and tree density as habitat elements affecting nest site selection. There are no critical biological activities and processes that directly affect nest site selection.

5. **Nest Attendance** – The breeding adult must attend the nest to incubate eggs, brood young, and feed young.

   The CEM recognizes anthropogenic disturbance, brood size, humidity, predator density, and temperature as habitat elements affecting nest attendance. Disease and foraging are the critical biological activities and processes that directly affect nest attendance.

6. **Temperature Regulation** – The adult must maintain an optimum temperature to survive.

   The CEM recognizes humidity and temperature as well as canopy closure and intermediate structure as primary habitat elements affecting temperature regulation. The critical biological activity and process of disease directly affects temperature regulation.

7. **Molt** – The adult must undergo a post-nuptual molt, and the process begins on the breeding grounds. This activity takes resources that must be directed from other biological processes. Molt requires food (through foraging) and is impacted by disease.

   The CEM does not recognize any habitat variables as directly affecting molt.

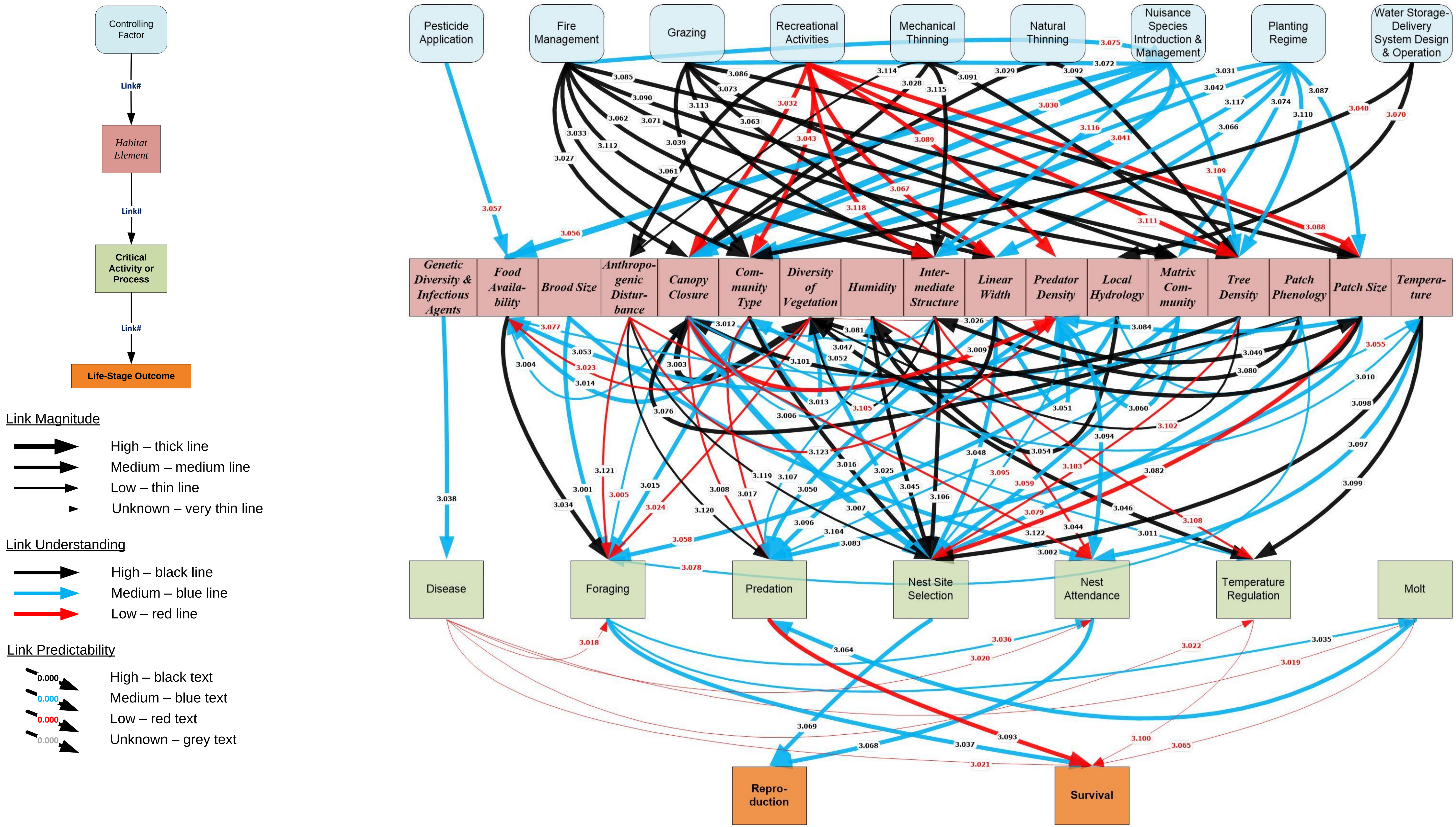

Figure 7.—YBCU life stage 3 – breeding adult, basic CEM diagram showing the relevant controlling factors, habitat elements, and critical biological activities and processes at this life stage.

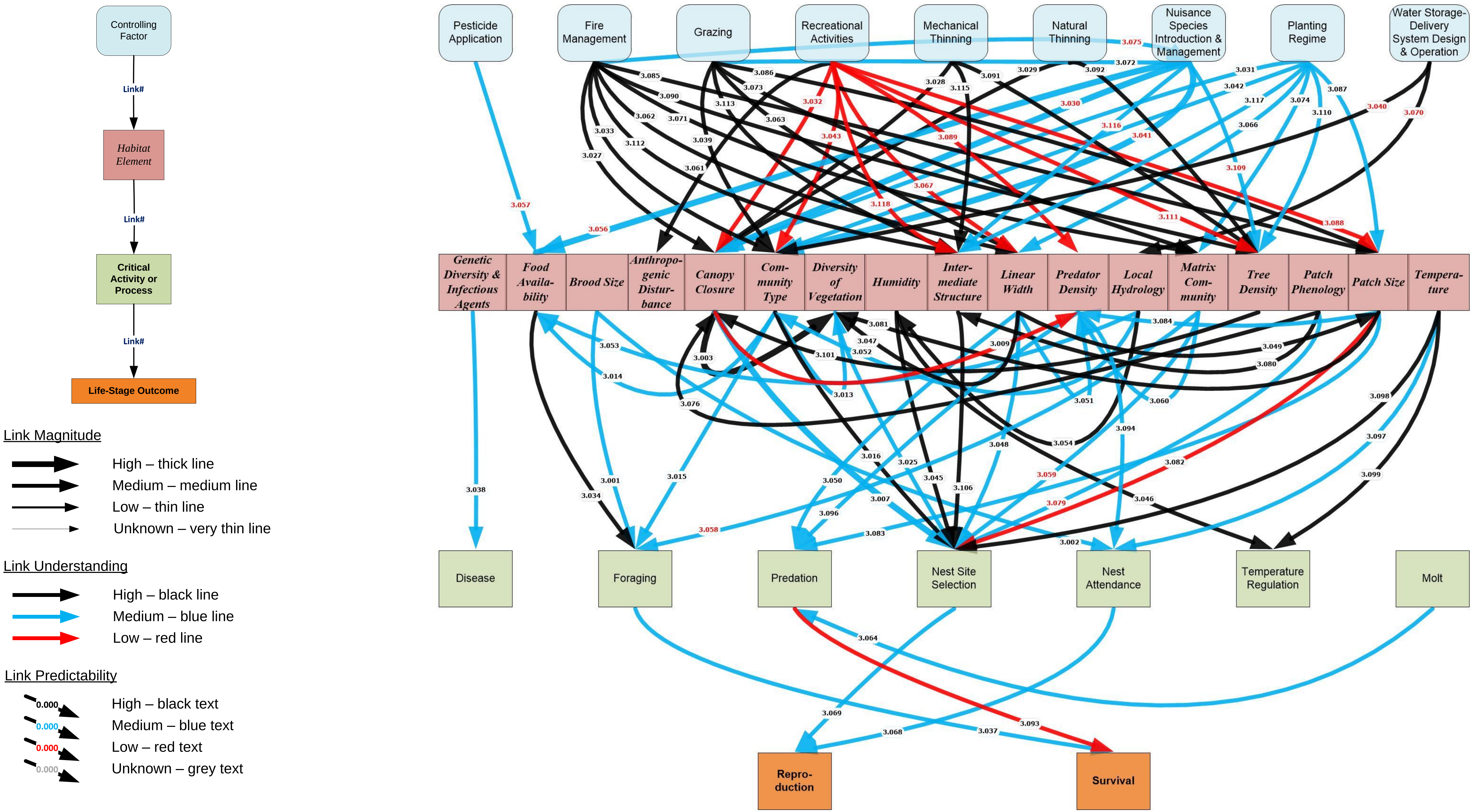

Figure 8.—YBCU life stage 3 – breeding adult, high- and medium-magnitude relationships showing the relevant controlling factors, habitat elements, and critical biological activities and processes at this life stage.

Chapter 7 – Causal Relationships Across All Life Stages

The nine controlling factors discussed in chapter 5 have the same influence on the same habitat elements for all life stages for which those habitat elements matter. Table 5 shows the magnitudes of *direct* influence of the 9 controlling factors on the 19 habitat elements. The structure of table 5 is the same as for table 4, but table 5 shows the magnitudes of the relationships instead of just their presence/absence. The paragraphs following the table discuss the relative effects of the different controlling factors on each habitat element. The magnitudes of direct influences of controlling factors on habitat elements is color coded in the table as follows:

High = H, Medium = M, Low = L

Table 5.—Magnitude of influence of controlling factors on habitat elements

Controlling factor ➔ / **Habitat element affected ➔**	**Fire management**	**Grazing**	**Mechanical thinning**	**Natural thinning**	**Nuisance species introduction and management**	**Pesticide/herbicide application**	**Planting regime**	**Recreational activities**	**Water storage-delivery system design and operation**
Anthropogenic disturbance			**L**					**M**	
Brood size	N/A*								
Canopy closure	**M**		**M**	**M**	**H**		**M**	**M**	
Community type	**M**	**M**			**H**		**M**	**M**	**M**
Diversity of vegetation	**N/A***								
Food availability					**H**	**M**			
Genetic diversity and infectious agents	N/A*								
Humidity	N/A*								
Intermediate structure	**M**	**M**	**M**		**M**		**M**	**M**	
Linear width of patch	**M**	**M**					**M**	**M**	
Local hydrology									**M**
Matrix community	**M**	**M**					**M**		
Parental feeding behavior	N/A*								
Parental nest attendance	N/A*								
Patch phenology	N/A*								
Patch size	**M**	**M**					**M**	**M**	
Predator density								**M**	
Temperature	N/A*								
Tree density	**M**		**M**	**M**	**M**		**M**	**M**	

* N/A values suggest that none of the identified controlling factors *directly* affect the habitat element.

ANTHROPOGENIC DISTURBANCE

The controlling factors that affect anthropogenic disturbance are mechanical thinning and recreational activities.

Mechanical thinning can increase noise levels at a site, which may affect nesting birds when done during the breeding season. Decisions regarding management of recreational activities can affect large areas, but the effects of a change in recreational activities on human disturbance would last far less than a decade; noise is an inherently short-term phenomenon.

Increases in recreation should lead to more humans present in riparian areas, and this can increase noise levels depending on the activity. The intensity of this link is likely proportional.

CANOPY CLOSURE

The controlling factors that directly affect canopy closure include fire management, mechanical thinning, natural thinning, nuisance species introduction and management, planting regime, and recreational activities. Fire management, mechanical thinning, and recreational activities will generally reduce canopy closure, whereas the effects of nuisance species introduction and management and planting regime depend on the management actions and species involved.

Fire management is usually implemented over large areas and can have great effects on canopy closure. However, the dynamic nature of both fire and riparian communities means that effects of fire management will likely last less than a decade.

Mechanical thinning would be done at the patch level with effects lasting until the canopy grows back, and can be as intense as managers wish.

Although natural thinning affects canopy closure, it works on small scales, creating forest gaps, with the effect only lasting until the vegetation grows back.

Nuisance species can change the structure of entire communities, with lasting effects (Di Tomaso 1998). Although the effects are experienced at a patch level, invasive species can spread across entire regions, and their effects can last decades.

Planting regimes have the ability to greatly affect canopy closure. However, planting decisions are made at the scale of individual restoration sites. Although riparian communities tend to be ephemeral, restoration sites are heavily managed, so the effects are likely medium or even long term.

The potential impact of recreational activities on canopy closure is great, although it depends on the type and duration of the activity and how well it is managed. Decisions regarding management of recreational activities can affect large areas, but the dynamic nature of both human activity and riparian communities means that effects of recreational activities (depending on type, intensity, and effectiveness of management) will likely last less than a decade when appropriately managed.

COMMUNITY TYPE

The controlling factors that directly affect community type include fire management, grazing, nuisance species introduction and management, planting regime, recreational activities, and water storage-delivery system design and operation. It is not possible to state whether the effects of controlling factors are positive or negative.

Fire management can have great effects on the type of vegetation growing in a given patch, and is usually implemented over large areas. However, the dynamic nature of both fire and riparian communities means that effects of fire management will likely last less than a decade.

Grazing affects many aspects of vegetation structure and composition (Kauffman et al. 1997). The USFWS (2011) discusses potential effects of grazing on YBCU, and both Arizona (Latta et al. 1999) and Utah Partners in Flight (Parrish et al. 2002) recommend reducing grazing near riparian zones as a management action for YBCU. Grazing activity can heavily affect community type and is often implemented over large and long scales. However, the dynamic nature of riparian communities means that the effects of grazing will likely last less than a decade.

Nuisance species introduction and management can change the structure of entire communities, with lasting effects. Although the effects are experienced at a patch level, invasive species can spread across entire regions, and their effects can last decades unless a permanent transition occurs.

Planting regimes have the ability to greatly affect vegetation. However, planting decisions are made at the scale of individual restoration sites. Although riparian communities tend to be ephemeral, restoration sites are heavily managed, so the effects are likely medium or even long term.

The USFWS (2002a) states that recreational activities can affect the species composition of riparian forests.

Water storage and flow regimes can affect vegetation communities (Launer et al. 1990; Halterman and Laymon 1994; Shafroth et al. 2000; Stromberg 2001), and nuisance or invasive species can change the structure of entire communities (Sogge et al. 2008; USFWS 2011), with lasting effects.

FOOD AVAILABILITY

The controlling factors that directly affect the food available to YBCU are nuisance species introduction and management and pesticide/herbicide application.

Important food items for YBCU, such as annual cicadas, are associated with native vegetation like cottonwoods (Smith et al. 2006), and therefore, introduced species may have a negative impact on food resources. Although most arthropods are vagile and can immigrate from other areas (Wiesenborn and Heydon 2007), the effects of nuisance species introduction can spread across entire regions and result in a permanent transformation of the landscape.

The magnitude of the effect of pesticides/herbicides depends on many factors, but the potential magnitude is great. The most likely scenario involves pesticide/herbicide applications at individual agricultural fields affecting nearby patches and the effects dissipating less than a decade after application.

INTERMEDIATE STRUCTURE

The controlling factors that directly affect intermediate structure include fire management, grazing, mechanical thinning, nuisance species introduction and management, planting regime, and recreational activities. Fire management, grazing, mechanical thinning, and recreational activities will generally reduce the intermediate structure, whereas the effects of nuisance species introduction and management and the planting regime depend on the management actions and species involved.

Fire management can have great effects on the type of vegetation growing in a given patch and is usually implemented over large areas. However, the dynamic nature of both fire and riparian communities means that effects of fire management will likely last less than a decade.

Grazing affects many aspects of the riparian vegetation structure and composition (Kauffman et al. 1997). Grazing activity can have great effects on community composition and is often implemented over large and long scales (Kauffman et al.

1997). However, the dynamic nature of riparian communities means that effects of grazing will likely last less than a decade but only if grazing is removed and a permanent transition of the habitat has not occurred.

Mechanical thinning is generally performed at the patch level, with effects lasting until vegetation grows back, and can be as intense as managers deem necessary.

Nuisance species introduction and management can change the structure of entire communities, with lasting effects. Although the effects are experienced at a patch level, invasive species can spread across entire regions, and their effects can last decades.

Planting regimes have the ability to greatly affect vegetation. However, planting decisions are made at the scale of individual restoration sites.

The potential impact of recreational activities on YBCU habitat is great, although it depends on the activity. Decisions regarding management of recreational activities can affect large areas.

LINEAR WIDTH OF PATCH

The controlling factors that directly affect the width of a given patch of riparian vegetation include fire management, grazing, planting regime, and recreational activities. Fire management, grazing, and recreational activities will generally reduce the width of a riparian patch, whereas the effects of the planting regime depend on the management actions and species involved.

Fire management can have great effects on the width of a given patch and is usually implemented over large areas. However, the dynamic nature of both fire and riparian communities means that effects of fire management will likely last less than a decade.

Grazing affects many aspects of vegetation structure and composition (Kauffman et al. 1997). The USFWS (2011) discusses the potential effects of grazing on YBCU and both Arizona (Latta et al. 1999) and Utah Partners in Flight (Parrish et al. 2002) recommend reducing grazing near riparian zones as a management action for YBCU. Grazing activity can heavily affect the width of a patch and is often implemented over large and long scales. However, the dynamic nature of riparian communities means that effects of grazing will likely last less than a decade.

Planting regimes have the ability to greatly affect the linear width of a patch. However, planting decisions are made at the scale of individual restoration sites. Although riparian communities tend to be ephemeral, restoration sites are heavily managed, so the effects are likely medium or even long term.

The USFWS (2002a) states that recreational activities can affect riparian vegetation. Therefore, the potential impact of recreational activities on YBCU habitat is great, although it depends on the type and duration of the activity and how well it is managed. Decisions regarding management of recreational activities can affect large areas, but the dynamic nature of both human activity and riparian communities means that effects of recreational activities will likely last less than a decade.

LOCAL HYDROLOGY

The only controlling factor affecting local hydrology is water storage-delivery system design and operation—it is not possible to put a direction on the effect. The amount of water released or stored affects water levels, and therefore, the distance to water, soil moisture, and other hydrological conditions. Water storage and flow regimes can affect vegetation communities and food abundance (Launer et al. 1990; Halterman and Laymon 1994; Shafroth et al. 2000; Stromberg 2001; Nilsson and Svedmark 2002; Lite et al. 2005). The effects of water storage spread over large scales, but the effects of changes in flow regimes will likely last less than a decade unless a complete transformation of the habitat occurs.

MATRIX COMMUNITY

The controlling factors that directly affect the matric community include fire management, grazing, and the planting regime. It is not possible to assign a direction on the effects of controlling factors.

Fire management can have great effects on the matrix community and is usually implemented over large areas. However, the dynamic nature of both fire and riparian communities means that the effects of fire management will likely last less than a decade.

Grazing affects many aspects of vegetation structure and composition (Kauffman et al. 1997). The USFWS (2011) discusses the potential effects of grazing on YBCU, and both Arizona (Latta et al. 1999) and Utah Partners in Flight (Parrish et al. 2002) recommend reducing grazing near riparian zones as a management action for YBCU. Grazing activity can heavily affect the matrix community and is often implemented over large and long scales. However, the dynamic nature of riparian communities means that the effects of grazing will likely last less than a decade.

Planting regimes have the ability to greatly affect vegetation. However, planting decisions are made at the scale of individual restoration sites. Restoration sites are heavily managed, so the effects are likely medium or even long term.

PATCH SIZE

The controlling factors that directly affect patch size include fire management, grazing, planting regime, and recreational activities. Fire, grazing, and recreational activities will generally reduce the size of a given patch, whereas the effects of the planting regime depend on the management actions and species involved.

Fire affects many aspects of vegetation structure and composition and can destroy habitat (Engstrom et al. 1984). Fire management can have great effects on the vegetation structure and, thus, patch size, and it can be implemented over either small or large areas. However, the dynamic nature of both fire and riparian communities means that the effects of fire management will likely be short term.

Grazing affects many aspects of riparian vegetation structure and composition (Kauffman et al. 1997). Grazing activity can have great effects on community composition and patch size and is often implemented over large and long scales (Kauffman et al. 1997). However, the dynamic nature of riparian communities means that the effects of grazing will likely be short term in nature unless a permanent transition in the patch occurs.

Planting regimes have the ability to greatly affect vegetation. However, planting decisions are made at the scale of individual restoration sites. Although riparian communities tend to be ephemeral, restoration sites are heavily managed, so the effects are likely medium or even long term, and patch size can be integrated into restoration planning.

Recreational activities can influence the species composition of riparian forests, although it depends on the activity.

PREDATOR DENSITY

The controlling factor that directly affects predator density is recreational activities. The direction and size of its effects are difficult to quantify.

Recreational activities can influence predator densities by increasing predator success rates by interfering with prey, distracting the predator, or by decreasing success rates by predator disturbance or predator interference (Mason 2015; Ware et al. 2015).

TREE DENSITY

The controlling factors that directly affect tree density include fire management, mechanical thinning, natural thinning, nuisance species introduction and management, planting regime, and recreational activities. Fire management, mechanical/natural thinning, and recreational activities will generally reduce tree density, whereas the effects of nuisance species introduction and management and the planting regime depend on the management actions and species involved.

Fire affects many aspects of vegetation structure and composition and can destroy YBCU habitat (Engstrom et al. 1984). Fire management can have great effects on the vegetation structure and is usually implemented over large areas. However, the dynamic nature of both fire and riparian communities means that effects of fire management will likely last less than a decade.

Mechanical thinning is generally performed at the patch level, with effects lasting until vegetation grows back, and can be as intense as managers deem necessary.

Although natural thinning affects tree density, it works on small scales, creating forest gaps. The effect only lasts until the vegetation grows back.

Nuisance species introduction and management can change the structure of entire communities, with lasting effects. Although the effects are experienced at a patch level, invasive species can spread across entire regions, and their effects can last decades unless a permanent transition occurs.

Planting regimes have the ability to greatly affect vegetation. However, planting decisions are made at the scale of an individual restoration site. Although riparian communities tend to be ephemeral, restoration sites are heavily managed, so the effects are likely medium or even long term.

The potential impact of recreational activities on tree density in YBCU habitat is great, although it depends on the activity. Decisions regarding management of recreational activities can affect large areas.

Chapter 8 – Discussion and Conclusions

This chapter summarizes the findings of this assessment in three ways by posing three questions: (1) which critical biological activities and processes most strongly affect the individual life stages across all life stages, (2) which habitat elements, in terms of their abundance, distribution, and quality, most strongly affect the most influential activities and processes, and (3) which of these causal relationships appear to be the least understood in ways that could affect their management?

MOST INFLUENTIAL ACTIVITIES AND PROCESSES ACROSS ALL LIFE STAGES

Figure 9 identifies the critical biological activities and processes that this assessment found most strongly directly or indirectly affect the success of YBCU in each life stage (high or medium magnitude). The findings presented in this diagram may be summarized as follows:

- Eating, foraging, and predation are the most important critical biological activities and processes affecting survival of YBCU in all life stages (Fontaine and Martin 2006; Martin 2011). Hughes (1999) suggests that YBCU populations are often limited by food availability, implying that the YBCU's ability to forage is especially important. Other processes, such as disease, molt, and temperature regulation can be very important, but are less understood, especially within the LCR.

- Only two processes directly affect reproduction—nest attendance and nest site selection. Nest site selection is especially important, as it can indirectly influence survival of YBCU in all life stages. For example, good nest sites may be in close proximity to more food, have fewer predators, and have fewer diseases present.

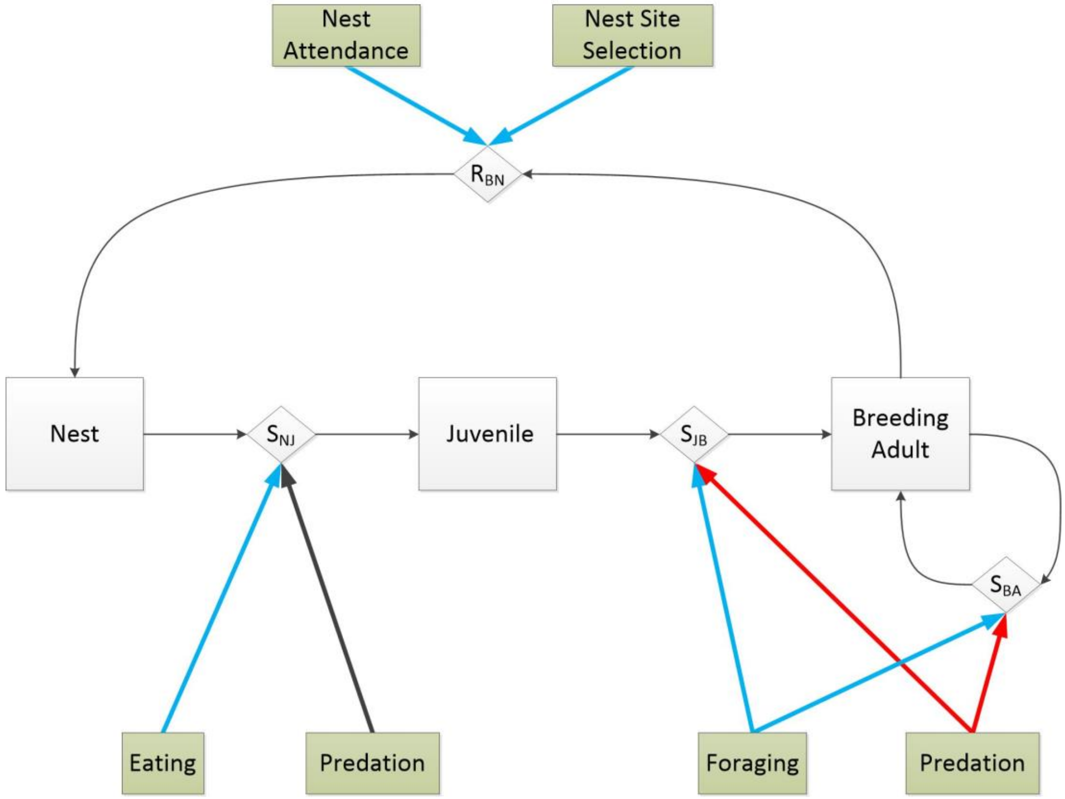

Figure 9.—Most influential biological activities and processes affecting each life stage of YBCU. Only elements with high- or medium-magnitude connections are presented. The legend is provided on figure 2.

POTENTIALLY PIVOTAL ALTERATIONS TO HABITAT ELEMENTS

Figure 10 identifies the habitat elements that this assessment indicates most strongly directly or indirectly affect the critical biological activities and processes identified on figure 9 across all life stages (high or medium magnitude). The findings presented in this diagram may be summarized as follows:

- Nest site selection is by far affected by the most habitat variables likely because this critical biological activity and process is not only the most researched among those on figure 10 but also because during the breeding season, nest site selection determines if the birds are present or not.

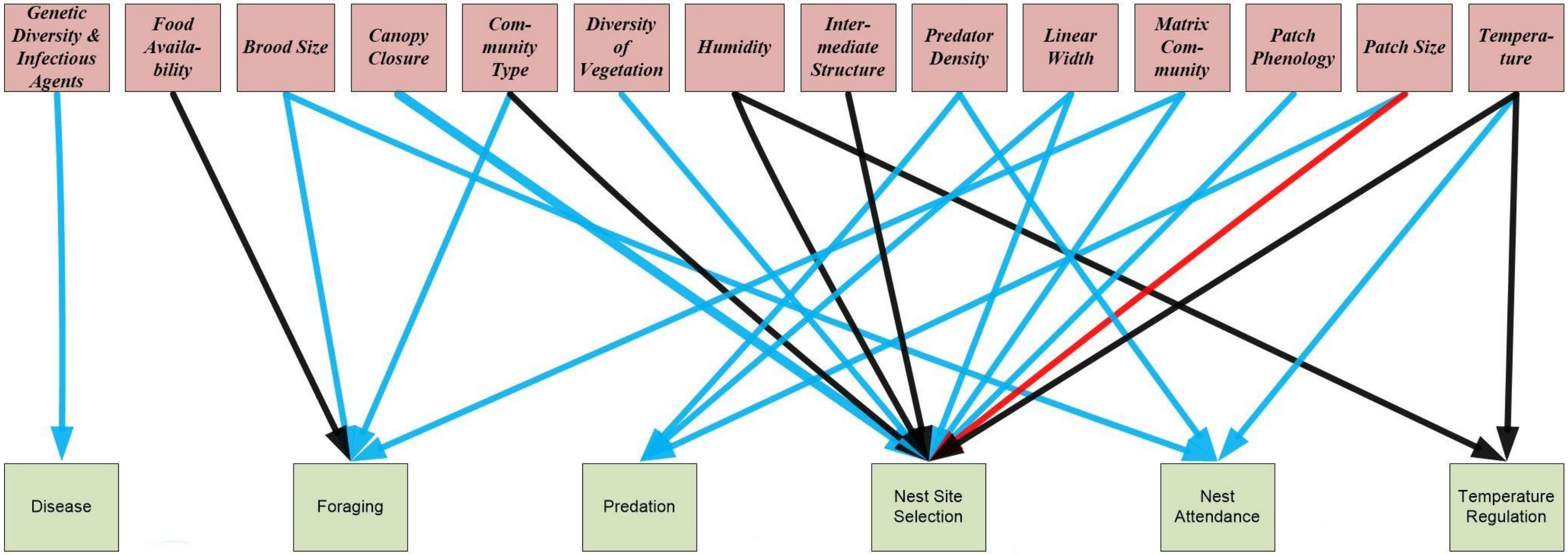

Figure 10.—Habitat elements that directly or indirectly affect the most influential biological activities and processes across all life stages of YBCU. Only elements with high- or medium-magnitude connections are presented. The legend is provided on figure 2.

- Predation is also affected by a large number of habitat elements, including anthropogenic disturbance, canopy closure, community type, intermediate structure, linear width of patch, patch size, predator density, and tree density, along with parental nest attendance and parental feeding behavior. Patch size affects predation rates because of its effects on the proportion of edge (Theimer et al. 2011; Laymon and Halterman 1989 and references therein). Predator density affects predation rates (Schmidt et al. 2001). Predation is affected by edges (reviewed by Yahner 1988), and linear width affects how much of the area of a patch is affected by edge effects.

- Nest attendance is strongly affected by four habitat elements, including anthropogenic disturbance, brood size, predator density, and temperature. Anthropogenic disturbance may cause adult birds to flush and stay away from the nest (Burhans and Thompson, III 2001; USFWS 2002a). Brood size affects the amount of time YBCU must spend foraging versus attending the nest (Hughes 1999). Predator density certainly affects predation rates (Schmidt et al. 2001). The temperature affects nest attendance of birds along the LCR (Theimer et al. 2011).

GAPS IN UNDERSTANDING

Figures 9 and 10 use the conventional color coding of individual causal relationships to identify relationships that the CEM identifies as having high, intermediate, or low levels of scientific confirmation. As noted in attachment 1, "Low" scientific understanding of a relationship means that it is "…subject to wide disagreement or uncertainty in peer-reviewed studies from within the ecosystem of concern and in scientific reasoning among experts familiar with the ecosystem." In many cases, the scientific principles are well understood, but the factual details are insufficiently understood within the LCR. The two figures show large numbers of red arrows, indicating relationships that the assessment identifies as having a low level of scientific understanding. Each of these red arrows identifies a causal relationship that may warrant further field, laboratory, or literature investigation. The following highlights some potentially important areas of low understanding:

- The effects of predation on juveniles and adults is poorly understood, whereas nest predation is better studied. This likely reflects the relative ease of studying depredation of nests versus free-flying birds. Since the persistence or population growth of YBCU populations is as sensitive to the survival of adults and juveniles as nest survival, more information regarding depredation of YBCU in these life stages would be valuable.

- We have classified the relationship between patch size and nest site selection as poorly understood. Past authors agree patch size is important (e.g., Laymon and Halterman 1989; Halterman 1991; Hughes 1999), but the home ranges and the sizes of the patches used varies regionally. For example, McNeil et al. (2013a) found that YBCU had smaller home ranges (approximately 21 hectares) in restoration sites than were observed on more natural sites (approximately 38 and 56 hectares) at other locations.

- Several authors mention food, especially cicadas and other large insects, as important for YBCU (Laymon et al. 1997; Hughes 1999; Wiggins 2005; Smith et al. 2006). We have therefore classified the relationship between food availability and foraging as well understood. However, although the relationship between food availability and YBCU persistence likely holds across its range, the specific prey base at LCR MSCP restoration sites is poorly known (McNeil et al. 2013).

- YBCU are sensitive to disturbance of all kinds, and a better understanding of the impacts of all forms of anthropogenic disturbance would be valuable.

This list of uncertainties is not meant to be exhaustive but only to highlight topics the literature identifies as potentially pivotal to YBCU recruitment along the LCR and to identify important gaps in these publications. They are not in any way to be considered guidance for Reclamation or LCR MSCP, nor are these knowledge gaps expected to be addressed under the program.

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ATTACHMENT 1

Species Conceptual Ecological Model Methodology for the Lower Colorado River Multi-Species Conservation Program

OVERVIEW OF METHODOLOGY

The conceptual ecological models (CEMs) for species covered by the Lower Colorado River Multi-Species Conservation Program (LCR MSCP) Habitat Conservation Plan expand on a methodology developed by the Sacramento-San Joaquin Delta Ecosystem Restoration Program (ERP): https://www.dfg.ca.gov/ERP/conceptual_models.asp. The ERP is jointly implemented by the California Department of Fish and Wildlife, U.S. Fish and Wildlife Service, and National Marine Fisheries Service. The Bureau of Reclamation participates in this program.

The ERP methodology incorporates common best practices for constructing CEMs for individual species (Wildhaber et al. 2007; Fischenich 2008; DiGennaro et al. 2012). It has the following key features:

- It focuses on the *major life stages or events* through which each species passes and the *output(s)* of each life stage or event. Outputs typically consist of survivorship or the production of offspring.

- It identifies the *major drivers* that affect the likelihood (rate) of each output. Drivers are physical, chemical, or biological factors – both natural and anthropogenic – that affect output rates and therefore control the viability of the species in a given ecosystem.

- It characterizes these interrelationships using a "*driver-linkage-outcomes*" approach. Outcomes are the output rates. Linkages are cause-effect relationships between drivers and outcomes.

- It *characterizes each causal linkage* along four dimensions: (1) the character and direction of the effect, (2) the magnitude of the effect, (3) the predictability (consistency) of the effect, and (4) the certainty of present scientific understanding of the effect (DiGennaro et al. 2012).

The CEM methodology used for species covered by the LCR MSCP Habitat Conservation Plan species expands this ERP methodology. Specifically, the present methodology incorporates the recommendations and examples of Wildhaber et al. (2007), Kondolf et al. (2008), Burke et al. (2009), and Wildhaber (2011) for a more hierarchical approach and adds explicit demographic notation for the characterization of life-stage outcomes (McDonald and Caswell 1993). This expanded approach provides greater detail on causal linkages and outcomes. The expansion specifically calls for identifying **four** types of model components for each life stage, and the causal linkages among them, as follows:

- **Life-stage outcomes** are outcomes of an individual life stage, including the recruitment of individuals to the next succeeding life stage (e.g., juvenile to adult). For some life stages, the outcomes, alternatively or additionally, may include the survival of individuals to an older age class within the same life stage or the production of offspring. The rates of life-stage outcomes depend on the rates of the critical biological activities and processes for that life stage.

- **Critical biological activities and processes** are activities in which a species engages and the biological processes that must take place during each life stage that significantly affect life-stage outcomes. They include activities and processes that may benefit or degrade life-stage outcomes. Examples of critical biological activities and processes include mating, foraging, avoiding predators, avoiding other specific hazards, gamete production, egg maturation, leaf production, and seed germination. Critical biological activities and processes are "rate" variables. Taken together, the rate (intensity) of these activities and processes determine the rates of different life-stage outcomes.

- **Habitat elements** are specific habitat conditions that significantly ensure, allow, or interfere with critical biological activities and processes. The full suite of natural habitat elements constitutes the natural habitat template for a given life stage. Human activities may introduce habitat elements not present in the natural habitat template. Defining a habitat element may involve estimating the specific ranges of quantifiable properties of that element *whenever the state of knowledge supports such estimates*. These properties concern the abundance, spatial and temporal distributions, and other qualities of the habitat element that significantly affect the ways in which it ensures, allows, or interferes with critical biological activities and processes.

- **Controlling factors** are environmental conditions and dynamics – both natural and anthropogenic – that determine the quality, abundance, and spatial and temporal distributions of one or more habitat elements. In some instances, a controlling factor alternatively or additionally may directly affect a critical biological activity or process. Controlling factors are also called "drivers." A hierarchy of controlling factors will exist, affecting the system at different temporal and spatial scales. Long-term dynamics of climate and geology define the domain of this hierarchy (Burke et al. 2009). For example, the availability of suitable nest sites for a riparian nesting bird may depend on factors such as canopy cover, community type, humidity, and intermediate structure which, in turn, may depend on factors such as water storage-delivery system design and operation (dam design, reservoir morphology, and dam operations) which, in turn, is shaped by watershed geology, vegetation, climate, land use, and water demand. *The LCR MSCP conceptual ecological models focus* *on controlling factors that are within the scope of potential human manipulation, including management actions directed toward the species of interest.*

The present CEM methodology also explicitly defines a "life stage" as a biologically distinct portion of the life cycle of a species. The individuals in each life stage undergo distinct developments in body form and function; engage in distinct types behaviors, including reproduction; use different sets of habitats or the same habitats in different ways; interact differently with their larger ecosystems; and/or experience different types and sources of stress. A single life stage may include multiple age classes. A CEM focused on life stages is not a demographic model *per se* (e.g., McDonald and Caswell 1993). Instead, it is a complementary model focused on the ecological factors (drivers) that shape population dynamics.

This expanded approach permits the consideration of **six** possible types of causal relationships, on which management actions may focus, for each life stage of a species:

(1) The effect of one controlling factor on another

(2) The effect of a controlling factor on the abundance, spatial and temporal distributions, and other qualities of a habitat element

(3) The effect of the abundance, spatial and temporal distributions, and other qualities of one habitat element on those of another

(4) The effect of the abundance, spatial and temporal distributions, and other qualities of a habitat element on a critical biological activity or process

(5) The effect of one critical biological activity or process on another

(6) The effect of a critical biological activity or process on a specific life-stage outcome

Each controlling factor may affect the abundance, spatial and temporal distributions, and other qualities of more than one habitat element and several controlling factors may affect the abundance, spatial or temporal distributions, or other qualities of each habitat element. Similarly, the abundance, spatial and temporal distributions, and other qualities of each habitat element may affect more than one biological activity or process, and the abundances, spatial or temporal distributions, or other qualities of several habitat elements may affect each biological activity or process. Finally, the rate of each critical biological activity or process may contribute to the rates of more than one life-stage outcome.

Integrating this information across all life stages for a species provides a detailed picture of: (1) what is known, with what certainty, and the sources of this information; (2) critical areas of uncertain or conflicting science that demand resolution to better guide LCR MSCP management planning and action; (3) crucial attributes to use to monitor system conditions and predict the effects of experiments, management actions, and other potential agents of change; and (4) how managers may expect the characteristics of a resource to change as a result of changes to controlling factors, including changes in management actions.

Conceptual Ecological Models as Hypotheses

The CEM for each species produced with this methodology constitutes a collection of hypotheses for that species. These hypotheses concern: (1) the species' life history; (2) the species' habitat requirements and constraints; (3) the factors that control the quality, abundance, and spatial and temporal distributions of these habitat conditions; and (4) the causal relationships among these. Knowledge about these model components and relationships may vary, ranging from well settled to very tentative. Such variation in the certainty of current knowledge always arises as a consequence of variation in the types and amount of evidence available and in the ecological assumptions applied by different experts.

Wherever possible, the information assembled for the LCR MSCP species CEMs documents the degree of certainty of current knowledge concerning each component and linkage in the model. This certainty is indicated by the quality, abundance, and consistency of the available evidence and by the degree of agreement/disagreement among the experts. Differences in the interpretations or arguments offered by different experts may be represented as alternative hypotheses. Categorizing the degree of agreement/disagreement concerning the components and linkages in a CEM makes it easier to identify topics of greater uncertainty or controversy.

Characterizing Causal Relationships

A causal relationship exists when a change in one condition or property of a system results in a change in some other condition or property. A change in the first condition is said to cause a change in the second condition. The present CEM methodology includes methods for assessing causal relationships (links) along four dimensions (attributes) adapted from the ERP methodology (DiGennaro et al. 2012):

(1) The character and direction of the effect

(2) The magnitude of the effect

(3) The predictability (consistency) of the effect

(4) The certainty of present scientific understanding of the effect

The present and ERP methodologies for assessing causal linkages differ in three ways. First, the ERP methodology assesses these four attributes for the *cumulative* effect of the entire causal chain leading up to each outcome. However, the LCR MSCP methodology recognizes six different types of causal linkages as described above. This added level of detail and complexity makes it difficult in a single step to assess the cumulative effects of all causal relationships that lead up to any one individual causal link. For example, in the present methodology, the effect of a given critical biological activity or process on a particular life-stage outcome may depend on the effects of several habitat elements on that critical biological activity or process which, in turn, may depend on the effects of several controlling factors. For this reason, the present methodology assesses the four attributes separately for each causal link *by itself* rather than attempting to assess cumulative effects of all causal linkages leading to the linkage of interest. The present methodology assesses cumulative effects instead through analyses of the data assembled on all individual linkages. The analyses are made possible by assembling the data on all individual linkages in a spreadsheet as described below.

Second, the present CEM methodology explicitly divides link magnitude into three separate subattributes and provides a specific methodology for integrating their rankings into an overall ranking for link magnitude: (1) link intensity, (2) link spatial scale, and (3) link temporal scale. In contrast, the ERP methodology treats spatial and temporal scale together and does not separately evaluate link intensity. The present methodology defines link intensity as the relative strength of the effect of the causal node on the affected node *at the places and times where the effect occurs*. Link spatial scale is the relative spatial extent of the effect of the causal node on the affected node. Link temporal scale is the relative temporal extent of the effect of the causal node on the affected node. The present methodology defines link magnitude as the average of the separate rankings of link intensity, spatial scale, and temporal scale as described below.

Third, the ERP methodology addresses a single, large landscape, while the present methodology needed the flexibility to generate models applicable to a variety of spatial scopes. For example, the present methodology needed to support modeling of a single restoration site, the LCR main stem and flood plain, or the entire Lower Colorado River Basin. Consequently, the present methodology assesses the spatial scale of cause-effect relationships only relative to the spatial scope of the model.

The LCR MSCP conceptual ecological model methodology thus defines the four attributes for a causal link as follows:

- **Link character** – This attribute categorizes a causal relationship as positive, negative, involving a threshold response, or "complex." "Positive" means that an increase in the causal node results in an increase in the affected node, while a decrease in the causal node results in a decrease in the affected node. "Negative" means that an increase in the causal node results in a decrease in the affected element, while a decrease in the causal node results in an increase in the affected node. Thus, "positive" or "negative" here do ***not*** mean that a relationship is beneficial or detrimental. The terms instead provide information analogous to the sign of a correlation coefficient. "Threshold" means that a change in the causal agent must cross some value before producing an effect. "Complex" means that there is more going on than a simple positive, negative, or threshold effect. In addition, this attribute categorizes a causal relationship as uni- or bi-directional. Bi-directional relationships involve a reciprocal relationship in which each node affects the other.

- **Link magnitude** – This attribute refers to "… the degree to which a linkage controls the outcome *relative to other drivers*" (DiGennaro et al. 2012). Magnitude takes into account the spatial and temporal scale of the causal relationship as well as the strength (intensity) of the relationship in individual locations. The present methodology provides separate ratings for the intensity, spatial scale, and temporal scale of each link, as defined above, and assesses overall link magnitude by averaging these three elements. Just as the terms for link character provide information analogous to the sign of a correlation coefficient, the terms for link magnitude provide information analogous to the size of a correlation coefficient. Tables 1-1 through 1-4 present the rating framework for link magnitude.

- **Link predictability** – This attribute refers to "… the degree to which the current understanding of the system can be used to predict the role of the driver in influencing the outcome. Predictability … captures variability … [and recognizes that] effects may vary so much that properly measuring and statistically characterizing inputs to the model are difficult" (DiGennaro et al. 2012). A causal relationship may be unpredictable because of natural variability in the system or because its effects depend on the interaction of other factors with independent sources for their own variability. Just as the terms for link character provide information analogous to the sign of a correlation coefficient, the terms for link predictability provide information analogous to the size of the range of error for a correlation coefficient. Table 1-5 presents the scoring framework for link predictability.

- **Link understanding** refers to the degree of agreement represented in the scientific literature and among experts in understanding how each driver is linked to each outcome. Table 1-6 presents the scoring framework for understanding. Link predictability and understanding are independent attributes. A link may be considered highly predictable but poorly understood or poorly predictable but well understood.

Conceptual Ecological Model Documentation

The documentation for each CEM provides information in three forms: (1) a narrative report, (2) causal diagrams showing the model components and their causal linkages for each life stage, and (3) a spreadsheet that is used to record the detailed information (e.g., linkage attribute ratings) for each causal linkage. The spreadsheet and diagrams, built using Microsoft Excel™ and Microsoft Visio™, respectively, are linked so that the diagrams provide a fully synchronized summary of the information in the spreadsheet.

The narrative report for each species presents the definitions and rationales for the life stages/events and their outcomes identified for the species' life history; the critical biological activities and processes identified for each life stage; the habitat elements identified as supporting or impeding each critical biological activity or process for each life stage; the controlling factors identified as affecting the abundance, spatial and temporal distributions, and other qualities of the habitat elements for each life stage; and the causal linkages among these model components.

The narrative report includes causal diagrams (*aka* "influence diagrams") for each life stage. These diagrams show the individual components or nodes of the model for that stage (life-stage outcomes, critical biological activities and processes, habitat elements, and controlling factors) and their causal relationships. The causal relationships (causal links) are represented by arrows indicating which nodes are linked and the directions of the causal relationships. The attributes of each causal link are represented by varying line thickness, line color, and other visual properties as shown on figure 1-1. The diagram conventions mostly follow those in the ERP methodology (DiGennaro et al. 2012).

The spreadsheet for each CEM contains a separate worksheet for each life stage. Each row in the worksheet for a life stage represents a single causal link. Table 1-7 lists the fields (columns) recorded for each causal link.

Link Attribute Ratings, Spreadsheet Fields, and Diagram Conventions

Table 1-1.—Criteria for rating the relative intensity of a causal relationship – one of three variables in the rating of link magnitude (after DiGennaro et al. 2012, Table 2)

Link intensity – the relative strength of the effect of the causal node on the affected node *at the places and times where the effect occurs*.	
High	Even a relatively small change in the causal node will result in a relatively large change in the affected node *at the places and times where the effect occurs*.
Medium	A relatively large change in the causal node will result in a relatively large change in the affected node; a relatively moderate change in the causal node will result in no more than a relatively moderate change in the affected node; and a relatively small change in the causal node will result in no more than a relatively small change in the affected node *at the places and times where the effect occurs*.
Low	Even a relatively large change in the causal node will result in only a relatively small change in the affected node *at the places and times where the effect occurs*.
Unknown	Insufficient information exists to rate link intensity.

Table 1-2.—Criteria for rating the relative spatial scale of a cause-effect relationship – one of three variables in the rating of link magnitude (after DiGennaro et al. 2012, Table 1)

Link spatial scale – the relative spatial extent of the effect of the causal node on the affected node. The rating takes into account the spatial scale of the cause and its effect.	
Large	Even a relatively small change in the causal node will result in a change in the affected node across a large fraction of the spatial scope of the model.
Medium	A relatively large change in the causal node will result in a change in the affected node across a large fraction of the spatial scope of the model; a relatively moderate change in the causal node will result in a change in the affected node across no more than a moderate fraction of the spatial scope of the model; and a relatively small change in the causal node will result in a change in the affected node across no more than a small fraction of the spatial scope of the model.
Small	Even a relatively large change in the causal node will result in a change in the affected node across only a small fraction of the spatial scope of the model.
Unknown	Insufficient information exists to rate link spatial scale.

Table 1-3.—Criteria for rating the relative temporal scale of a cause-effect relationship – one of three variables in the rating of link magnitude (after DiGennaro et al. 2012, Table 1)

Link temporal scale – the relative temporal extent of the effect of the causal node on the affected node. The rating takes into account the temporal scale of the cause and its effect.	
Large	Even a relatively small change in the causal node will result in a change in the affected node that persists or recurs over a relatively large span of time – decades or longer – even without specific intervention to sustain the effect.
Medium	A relatively large change in the causal node will result in a change in the affected node that persists or recurs over a relatively large span of time – decades or longer – even without specific intervention to sustain the effect; a relatively moderate change in the causal node will result in a change in the affected node that persists or recurs over only a relatively moderate span of time – one or two decades – without specific intervention to sustain the effect; a relatively small change in the causal node will result in a change in the affected node that persists or recurs over only a relatively short span of time – less than a decade – without specific intervention to sustain the effect.
Small	Even a relatively large change in the causal node will result in a change in the affected node that persists or recurs over only a relatively short span of time – less than a decade – without specific intervention to sustain the effect.
Unknown	Insufficient information exists to rate link temporal scale.

Table 1-4.—Criteria for rating the overall relative link magnitude of a cause-effect relationship based on link intensity, spatial scale, and temporal scale

Link magnitude – the overall relative magnitude of the effect of the causal node on the affected node based on the numerical average for link intensity, spatial scale, and temporal scale. (Calculated by assigning a numerical value of 3 to "High" or "Large," 2 to "Medium," 1 to "Low" or "Small," and not counting missing or "Unknown" ratings.)	
High	Numerical average ≥ 2.67
Medium	Numerical average ≥ 1.67 but < 2.67
Low	Numerical average < 1.67
Unknown	No subattribute is rated High/Large, Medium, or Low/Small, but at least one subattribute is rated Unknown.

Table 1-5.—Criteria for rating the relative predictability of a cause-effect relationship (after DiGennaro et al. 2012, Table 3)

Link predictability – the statistical likelihood that a given causal agent will produce the effect of interest.	
High	Magnitude of effect is largely unaffected by random variation or by variability in other ecosystem dynamics or external factors.
Medium	Magnitude of effect is moderately affected by random variation or by variability in other ecosystem processes or external factors.
Low	Magnitude of effect is strongly affected by random variation or by variability in other ecosystem processes or external factors.
Unknown	Insufficient information exists to rate link predictability.

Table 1-6.—Criteria for rating the relative understanding of a cause-effect relationship (after DiGennaro et al. 2012, Table 3)

Understanding – the degree of agreement in the literature and among experts on the magnitude and predictability of the cause-effect relationship of interest.	
High	Understanding of the relationship is subject to little or no disagreement or uncertainty in peer-reviewed studies from within the ecosystem of concern or in scientific reasoning among experts familiar with the ecosystem. Understanding may also rest on well-accepted scientific principles and/or studies in highly analogous systems.
Medium	Understanding of the relationship is subject to moderate disagreement or uncertainty in peer-reviewed studies from within the ecosystem of concern and in scientific reasoning among experts familiar with the ecosystem.
Low	Understanding of the relationship is subject to wide disagreement, uncertainty, or lack of evidence in peer-reviewed studies from within the ecosystem of concern and in scientific reasoning among experts familiar with the ecosystem.
Unknown	(*The "Low" rank includes this condition*).

Table 1-7.—Organization of the worksheet for each life stage

Col.	Label	Content
A	Species	Identifies the species being modeled by four-letter code.
B	Link#	Contains a unique identification number for each causal link.
C	Life Stage	Identifies the life stage affected by the link.
D	Causal Node Type	Identifies whether the causal node for the link is a controlling factor, habitat element, critical biological activity or process, or life-stage outcome.
E	Causal Node	Identifies the causal node in the link.
F	Effect Node Type	Identifies whether the effect node for the link is a controlling factor, habitat element, critical biological activity or process, or life-stage outcome.
G	Effect Node	Identifies the effect node in the link.
H	Link Reason	States the rationale for including the link in the conceptual ecological model, including citations as appropriate.
I	Link Character Type	Identifies the character of the link based on standard definitions.
J	Link Character Direction	Identifies whether the link is uni- or bi-directional.
K	Link Character Reason	States the rationale for the entries for Link Character Type and Link Character Direction, including citations as appropriate.
L	Link Intensity	Shows the rating of link intensity based on the definitions in table 1-1.
M	Link Spatial Scale	Shows the rating of link spatial scale based on the definitions in table 1-2.
N	Link Temporal Scale	Shows the rating of link temporal scale based on the definitions in table 1-3.
O	Link Average Magnitude	Shows the numerical average rating of link intensity, spatial scale, and temporal scale based on the definitions in table 1-4.
P	Link Magnitude Rank	Shows the overall rating of link magnitude based on the Link Average Magnitude, grouped following the criteria in table 1-4.
Q	Link Magnitude Reason	States the rationale for the ratings for link intensity, spatial scale, and temporal scale, with citations as appropriate.
R	Link Predictability Rank	Shows the rating of link predictability based on the definitions in table 1-5.
S	Link Predictability Reason	States the rationale for the rating of link predictability, with citations as appropriate.
T	Link Understanding Rank	Shows the rating of link understanding based on the definitions in table 1-6.
U	Link Understanding Reason	States the rationale for the rating of link predictability, including comments on alternative interpretations and publications/experts associated with different interpretations when feasible, with citations as appropriate.
V	Management Questions	Briefly notes questions that appear to arise from the preceding entries for the link, focused on critical gaps or uncertainties in knowledge concerning *management actions and options*, with reasoning, including the estimate of relative importance when possible.
W	Research Questions	Brief notes that appear to arise from the preceding entries for the link, focused on critical gaps or uncertainties in *basic scientific knowledge*, with reasoning, including the estimate of relative importance when possible.
X	Other Comments	Provides additional notes on investigator concerns, uncertainties, and questions.
Y	Update Status	Provides information on the history of editing the information on this link for updates carried out after completion of an initial version.

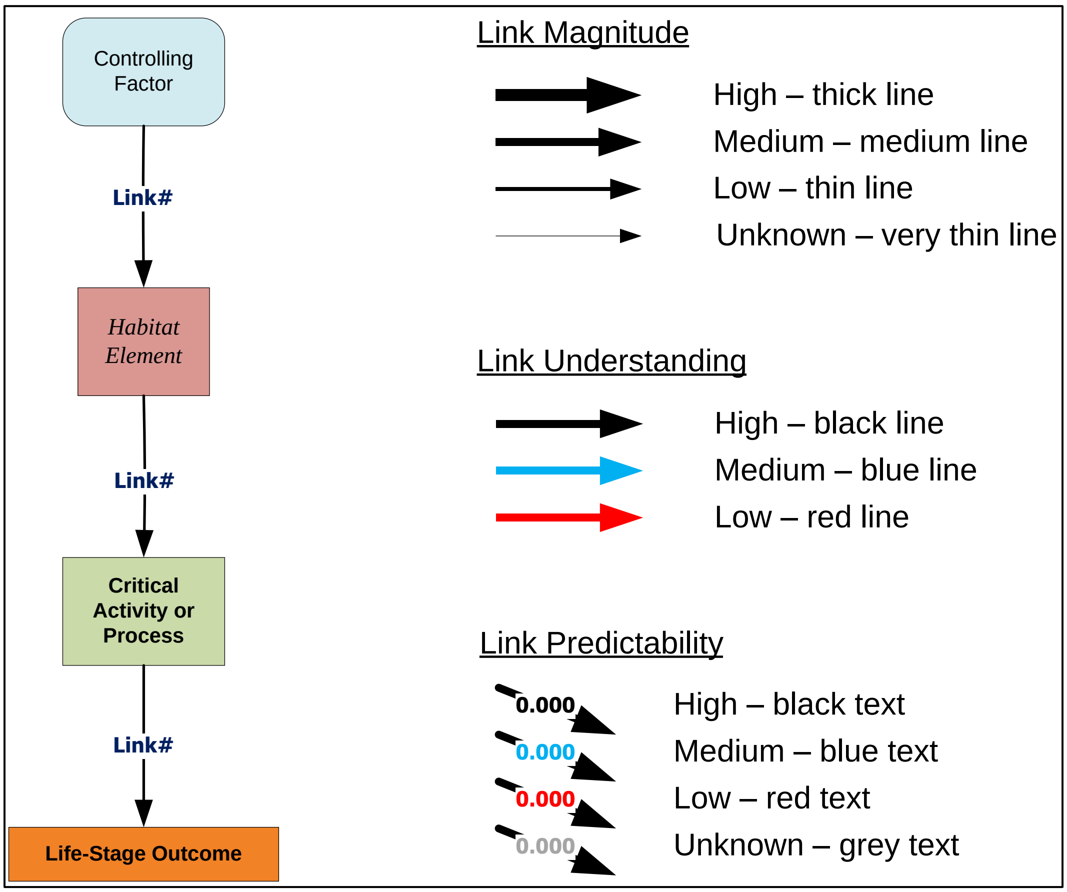

Figure 1-1.—Conventions for displaying cause and effect nodes, linkages, link magnitude, link understanding, and link predictability.

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ATTACHMENT 2

Western Yellow-billed Cuckoo Habitat Data

Table 2-1.—Western yellow-billed cuckoo habitat data

Habitat element	Value or range	Location	Reference
Canopy closure	89%	Lower Colorado River	Halterman 2001
	80%	Lower Colorado River	Halterman 2003
	67%	Lower Colorado River	Halterman 2004
	98% overall; 87% at nest	Lower Colorado River	McNeil et al. 2012
	93% at nest; 83.7% 5 meters from nest; 80% 10 meters from nest	Lower Colorado River	McNeil et al. 2013
	57%	Lower Colorado River	Johnson et al. 2006
Diversity of vegetation	No measurements, just descriptions		
Humidity	49.22 ± 0.83% relative humidity average at occupied sites – diurnal; 61.2 ± 0.93% relative humidity – nocturnal * Average 2008–12	Lower Colorado River	McNeil et al. 2013
Intermediate structure	80–90% – dense, low-level foliage	Lower Colorado River	Gaines and Laymon 1984
Linear width of patch	> 100 meters minimum	California	Gaines and Laymon 1984
	> 600 meters optimal	California	Laymon and Halterman 1989
	> 200 meters suitable	California	Laymon and Halterman 1989

Table 2-1.—Western yellow-billed cuckoo habitat data

Habitat element	Value or range	Location	Reference
Patch size	≥ 2 hectares (ha)	Lower Colorado River	Gaines and Laymon 1984
	Rarely found < 10 ha	California	California Department of Fish and Game 1987
	> 80 ha – optimal	California	Laymon and Halterman 1989
	40 – 80 ha – suitable	California	Laymon and Halterman 1989
	15-acre home range	California	Halterman 2004
	4-acre home range	Arizona	Halterman 2004
	5–20 ha	All	Halterman 2002
	59-ha subpatch	California	Girvetz and Greco 2009
	33.9 ha mean size of patch	Lower Colorado River	Halterman et al. 2009
	91 ha (minimum convex polygon), 62 ha (95% Kernal home range estimate)	New Mexico	Sechrist et al. 2013
	37.3 ± 19.5 ha mean size of patch	Lower Colorado River	McNeil et al. 2010
	Average home range 21.7 ± 10.4 ha; median size of occupied site: approximately 50 ha	Lower Colorado River	McNeil et al. 2011
	Medium-sized occupied sites 37.2 ha	Lower Colorado River	McNeil et al. 2013
	19.8 ha ± 9.7 ha	Lower Colorado River	McNeil et al. 2012
Temperature	32.51 degrees Celsius (°C) ± 0.15 °C average in occupied sites diurnal; 26.33 °C ± 0.16°C nocturnal * Average 2008–13	Lower Colorado River	McNeil et al. 2013
Tree density	> 150 trees/ha	California	Anderson and Laymon 1989

Note: The data presented in this table reflect those available in the literature at the time this model was developed. These data have not been validated.

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